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Technology for Large Space Systems
A Special Bibliography with Indexes

NASA SP-7046(02)
January 1980

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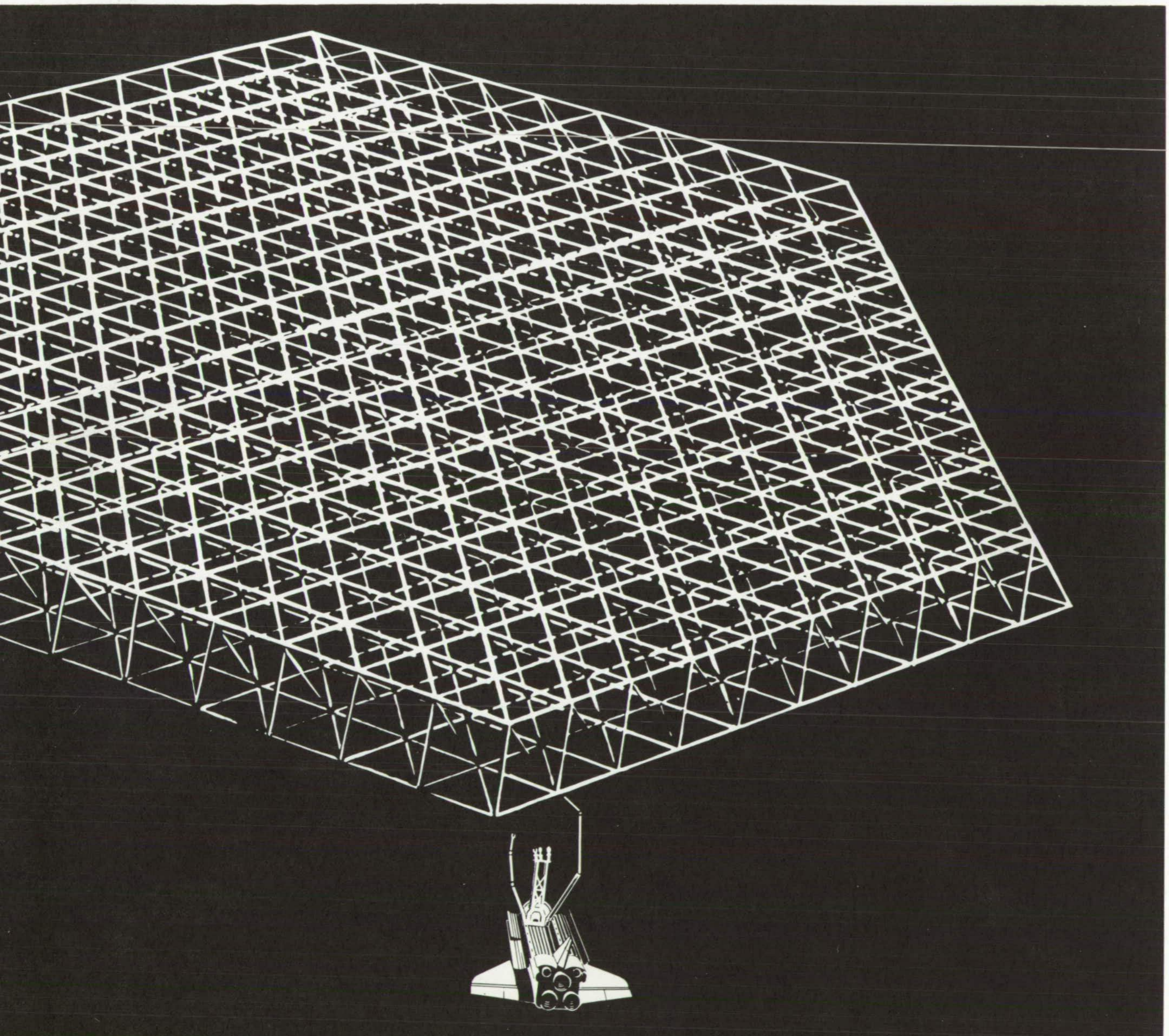

NASA SP-7046(02)

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A Special Bibliography With Indexes

Supplement 2

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced between July 1, 1979 and December 31, 1979.

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

NASA Scientific and Technical Information Branch 1980
National Aeronautics and Space Administration
Washington, DC

INTRODUCTION

This special bibliography is designed to be helpful to the researcher and manager engaged in developing technology within the discipline areas of the Large Space Systems Technology (LSST) Program. Also, the designers of large space systems for approved missions (in the future) will utilize the technology described in the documents referenced herein.

This literature survey lists 258 reports, articles and other documents announced between July 1, 1979 and December 31, 1979 in *Scientific and Technical Aerospace Reports (STAR)* and *International Aerospace Abstracts (IAA)*.

The coverage includes documents that define specific missions that will require large space structures to achieve their objectives. The methods of integrating advanced technology into system configurations and ascertaining the resulting capabilities is also addressed.

A wide range of structural concepts are identified. These include erectable structures which are earth fabricated and space assembled, deployable platforms and deployable antennas which are fabricated, assembled, and packaged on Earth with automatic deployment in space, and space fabricated structures which use pre-processed materials to build the structure in orbit.

The supportive technology that is necessary for full utilization of these concepts is also included. These technologies are identified as Interactive Analysis and Design, Control Systems, Electronics, Advanced Materials, Assembly Concepts, and Propulsion. Electronics is a very limited field in this bibliography, primarily addressing power and data distribution techniques.

This issue of the bibliography will also contain citations to documents dealing primarily with the Solar Power Satellite System (SPS) as will subsequent issues.

The reader will not find references to material that has been designated as "limited" distribution or security classified material. These types of documents will be identified by the LSST Program Office, and a separate listing will be distributed to selected recipients.

A Flight Experiments category and a General category complete the list of subjects addressed by this document.

The selected items are grouped into eleven categories as listed in the Table of Contents with notes regarding the scope of each category. These categories were especially selected for this publication and differ from those normally found in *STAR* and *IAA*.

Each entry consists of a standard bibliographic citation accompanied by an abstract where available. The citations and abstracts are reproduced exactly as they appeared originally in *STAR* and *IAA* including the original accession numbers from the respective announcement journals. This procedure accounts for the variation in citation appearance.

Under each of the eleven categories, the entries are presented in one of two groups that appear in the following order:

1) *IAA* entries identified by accession number series A79-10,000 in ascending accession number order;
2) *STAR* entries identified by accession number series N79-10,000 in ascending accession number order.

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TABLE OF CONTENTS

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NASA SPONSORED DOCUMENT — AVAILABLE ON MICROFICHE — NASA ACCESSION NUMBER — CORPORATE SOURCE — TITLE — AUTHORS — PUBLICATION DATE — CONTRACT OR GRANT — AVAILABILITY SOURCE — REPORT NUMBER

N79-16035*# Rockwell International Corp., Downey Calif. Space Division.
ADVANCED TECHNOLOGY REQUIREMENTS FOR LARGE SPACE STRUCTURES. PART 5: ATLAS PROGRAM REQUIREMENTS Final Report
E. Katz, A. N. Lillenas, and J. A. Broddy Sep. 1977 99 p
(Contract NAS1-14116)
(NASA-CR-159014; SD-77-AP-0162-Pt-5) Avail. NTIS HC A05/MF A01 CSCL 22B

The results of a special study which identifies and assigns priorities to technology requirements needed to accomplish a particular scenario of future large area space systems are described. Proposed future systems analyzed for technology requirements included large Electronic Mail, Microwave Radiometer, and Radar Surveillance Satellites. Twenty technology areas were identified as requirements to develop the proposed space systems. G.Y.

TYPICAL CITATION AND ABSTRACT FROM *IAA*

NASA SPONSORED DOCUMENT — AVAILABLE ON MICROFICHE — AIAA ACCESSION NUMBER — TITLE — AUTHOR — AUTHOR'S AFFILIATION — CONTRACT OR GRANT — MEETING — MEETING DATE

A79-21262 * # Technology requirements for an orbital navigation/position finding system. A. L. Lang, Jr. (Vought Corp., Dallas, Tex.) and L. J. DeRyder, Jr. (NASA, Langley Research Center, Space Systems Div., Hampton, Va.). *American Astronautical Society, Anniversary Conference, 25th, Houston, Tex., Oct. 30-Nov. 2, 1978, Paper 78-150*. 39 p. 23 refs. Contract No. NAS1-13500.

The concept of an orbiting personal navigation system as a possible application for a large space structure is considered. The navigation system would have to be part of a large, integrated, multifunction Information Service Platform to justify its complexity and assured use by a large segment of the civilian population. The navigation configuration is a large cruciform which utilizes a linear phased array antenna design. The two antenna arms generate narrow, orthogonal beam patterns on the ground which are electrically scanned east to west and south to north. A passive ground receiver detecting the beam passage determines the user's position in earth longitude and latitude coordinates. B.J.

TECHNOLOGY FOR LARGE SPACE SYSTEMS *A Special Bibliography (Suppl. 2)*

JANUARY 1980

01 SYSTEMS

Includes mission requirements, focus missions, conceptual studies, technology planning, and systems integration.

A79-34702 * # **Design and operations technologies - Integrating the pieces.** C. H. Eldred (NASA, Langley Research Center, Advanced Technology Group, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 5-11. 14 refs. (AIAA 79-0858)

As major elements of life-cycle costs (LCC) having critical impacts on the initiation and utilization of future space programs, the areas of vehicle design and operations are reviewed in order to identify technology requirements. Common to both areas is the requirement for efficient integration of broad, complex systems. Operations technologies focus on the extension of space-based capabilities and cost reduction through the combination of innovative design, low-maintenance hardware, and increased manpower productivity. Design technologies focus on computer-aided techniques which increase productivity while maintaining a high degree of flexibility which enhances creativity and permits graceful design changes. (Author)

A79-34742 * # **A technology program for large area space systems.** A. Guastaferro (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 343-353. (AIAA 79-0921)

The broad objective of the Large Space Systems Technology (LSST) program is to define and develop the necessary technology for large space systems and associated subsystems required for projected NASA space missions. It is a goal of LSST to make these systems economically and technically feasible by focusing on those technical activities believed to provide the greatest benefit to a variety of future systems. Emphasis is placed on two principal structural configurations: antennas and platforms. B.J.

A79-34761 * # **Global services systems - Space communication.** F. H. Shepphird and H. L. Wolbers (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 519-525. 10 refs. Contract No. NAS1-12346. NASA Task 28. (AIAA 79-0946)

The requirements projected to the year 2000 for space-based global service systems, including both personal communications and innovative services, are developed based on historic trends and anticipated worldwide demographic and economic growth patterns. The growing demands appear to be best satisfied by developing larger, more sophisticated space systems in order to reduce the size, complexity, and expense of ground terminals. The availability of low-cost ground terminals will, in turn, further stimulate the generation of new services and new customers. B.J.

A79-34762 * # **Space-based radio telescopes and an orbiting deep-space relay station.** R. V. Powell (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 526-534. 19 refs. Contract No. NAS7-100. (AIAA 79-0947)

Foremost among the candidates for early utilization of the Shuttle-launched self-deployable structures are the space-based radio telescopes. Several space-based telescopes are examined including an orbiting VLBI terminal, an orbiting submillimeter telescope, and a large ambient deployable IR telescope. Particular consideration is given to the high-gain Orbiting Deep-Space Relay Station for communication with deep-space probes. Details of deployable antenna technology are discussed. B.J.

A79-34868 **Technical challenges of large space systems in the 21st century.** T. J. Kelly (Grumman Aerospace Corp., Bethpage, N.Y.). In: The future United States space program; Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978. Part 2. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1979, p. 791-815. (AAS 78-195)

Exciting prospects exist in both the exploration and exploitation of space. Mission requirements are discussed relative to space science, space applications, and engineering support. Technical concepts and examples are considered in relation to structures, propulsion, stabilization and control, human factors, electronics, space manufacturing, and heat rejection systems. Implications for today are discussed with respect to need for supporting technology, dominance of economic considerations, and educational concerns for engineers. S.D.

A79-36549 # **Space structure - A key to new opportunities.** R. L. Kline (Grumman Aerospace Corp., Bethpage, N.Y.). *American Astronautical Society, Goddard Memorial Symposium, Washington, D.C., Mar. 28-30, 1979, Paper 79-059.* 15 p. 10 refs.

Applications of two future space structure techniques, Deployable Antennas and Space Construction/Satellite Servicing, and the means of achieving their practical usage are outlined. These space structures will be possible due to the Space Shuttle capability of delivering large, heavy payloads (up to 65,000 lb) into space with crews of space workers. Space structures provided by Construction Missions 1 to 5 are presented, and potential deployable antenna applications including multibeam communication repeater, electronic mail delivery, radar tracking of ground and airborne targets, and earth-looking radiometer are described. Space Construction/Servicing applications will range from development of the solar power satellite technology to space platform operations and satellite servicing. Space fabrication equipment is described, and the Manned Remote Work Station is discussed as an example of future satellite repair activities. It is concluded that space experimental demonstrations should be made to show prospective users that they can include the large deployable antenna and space fabrication/satellite servicing features in their future planning. A.T.

01 SYSTEMS

A79-45423 * # **A Microwave Radiometer Spacecraft, some control requirements and concepts.** U. M. Lovelace (NASA, Langley Research Center, Hampton, Va.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979. 8 p. (AIAA 79-1777)

A general overview of a conceptual design for a Microwave Radiometer Spacecraft using a large passive reflector, microwave radiometers, and advanced control concepts is presented. The mission requirements, developed around high resolution, large area mapping of soil moisture for global crop forecasting, are reviewed. These mission requirements, along with system design requirements, dictate the need for a reflector in excess of 700 meters in diameter. Conceptual designs for supporting structures and subsystems, including attitude and surface control, are summarized. (Author)

A79-50459 **The possibilities of SETI from space.** R. P. Basler (SRI International, Menlo Park, Calif.). *Cosmic Search,* vol. 1, Fall 1979, p. 41-45.

Radio systems to be used in the search for extraterrestrial intelligence (SETI) are discussed. Parameters involved in the choice of such a system are presented, and possible configurations for earth-based and orbiting systems and systems of radio antennas located on the far side of the moon are compared on the basis of cost, practicality and technical factors. An incremental SETI program based on the cumulative development and implementation of earth-based, then space-based radio telescopes is suggested, which would allow the completion of a search for extraterrestrial radio beacons in the 18 to 21-cm range by the second decade of the next century. Finally, motivations for the transmission of and search for extraterrestrial messages are discussed, and implications of the results of such a search for the future of advanced technological civilization are noted. A.L.W.

A79-51149 **Satellite clusters.** P. S. Visher (Hughes Aircraft Co., Aircraft Space and Communications Group, Culver City, Calif.). *Satellite Communications,* Sept. 1979, p. 22-24, 27.

Satellite clusters are proposed as an alternative to sophisticated space platforms to provide increased communications capacity at lower cost. Advantages discussed include simpler implementation, multiple reuse of frequencies, the capability to replace a single module if it fails, and indifference to a mixture of technologies. Attention is also given to the fact that less earth stations would be needed since each would have a greater capacity. Another benefit cited is that a 50 or 60 foot L-Band antenna could be introduced to greatly reduce the cost of ship-borne terminals, as well as search and rescue services. It is concluded that cluster capability could be implemented in four to five years. M.E.P.

A79-51892 **Orbital antenna farm power systems challenges.** F. H. Esch and W. L. Morgan (COMSAT Laboratories, Clarksburg, Md.). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings. Volume 2. Washington, D.C., American Chemical Society, 1979, p. 1207-1212. Research sponsored by the Communications Satellite Corp.

This paper describes possible orbital antenna farm (OAF) systems and identifies power system design problems which must be solved. The OAF is a space platform which combines a variety of communication services on a common platform and provides varying amounts of electric power depending on amounts of communications service. Long life and high reliability are economic justifications for OAF, so that an OAF platform is expected to operate for several decades. The platform capabilities of the several initial space stations of the OAF class and applications missions of the earliest OAF designs in the geostationary orbit are summarized. The platform power distribution among these missions, space station construction, and interconnected platforms for global traffic are discussed. The OAF electric power system, including nuclear and photovoltaic generators, and energy storage systems, such as thermoelectric conversion and rotating/moving devices are described. A.T.

A79-52674 * # **NASA technology for large space antennas.** R. A. Russell, T. G. Campbell (NASA, Langley Research Center, Hampton, Va.), and R. E. Freeland (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *NATO, AGARD, Structures and Materials Panel Meeting, 49th, Porz-Wahn, West Germany, Oct. 7-12, 1979, Paper.* 32 p. 14 refs.

Technology developed by NASA in conjunction with industry for potential large, deployable space antennas with applications in communication, radio astronomy and earth observation is reviewed. Concepts for deployable antennas that have been developed to the point of detail design are summarized, including the advanced sunflower precision antenna, the radial rib antenna, the maypole (hoop/column) antenna and the parabolic erectable truss antenna. The assessment of state-of-the-art deployable antenna technology is discussed, and the approach taken by the NASA Large Space Systems Technology (LSST) Program to the development of technology for large space antenna systems is outlined. Finally, the further development of the wrap-rib antenna and the maypole (hoop/column) concept, which meet mission model requirements, to satisfy LSST size and frequency requirements is discussed. A.L.W.

A79-53300 * **A technology base for near-term space platforms.** E. K. Huckins, III (NASA, Office of Aeronautics and Space Technology, Washington, D.C.) and A. Guastaferro (NASA, Langley Research Center, Hampton, Va.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-110.* 20 p. 18 refs.

The paper briefly describes the ongoing Large Space Systems Technology (LSST) Program in platform technology. The program addresses technology issues associated with the near-term science and applications platform, and the more fundamental questions associated with the general class of large space-assembled structural systems. Elements of the technology program are described and preliminary results are discussed. Results to date indicate that potential new capabilities of the Space Shuttle will strongly influence spacecraft design, and that future spacecraft utilizing these new capabilities can provide important new performance capabilities and greater efficiency. The proposed science and applications platform appears to be the earliest envisioned space vehicle which will be of the space-assembled class. S.D.

A79-53357 * **Orbital demonstration - The prelude to large operational structures in space.** T. Hagler (NASA, Office of Advanced Programs, Washington, D.C.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-207.* 16 p. Contracts No. NAS9-15310; No. NAS8-32394; No. NAS9-14916.

The paper surveys three specific large space structures which have been analyzed to determine the technology needed to achieve a fully operational system. These are the multipurpose platforms; satellite power systems, and a deployable antenna. Further attention is also given to those technology needs which can be satisfied by ground based technology (simulation), such as payload carrier modification or design, platform element connectors and fittings, data compression and storage equipment, man-machine interface and productivity assessment, and astronaut aids. Also covered are those technology and performance parameters which require demonstration in orbit. M.E.P.

A79-53358 * **New space initiatives through large generic structures.** R. W. Johnson (NASA, Washington, D.C.; Grumman Aerospace Corp., Bethpage, N.Y.). *International Astronautical Feder-*

tion, *International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-208*. 36 p. 6 refs.

New possibilities in satellite communications, surveillance, and orbital experimentation provided by the capability to construct and deploy Large Space Structures (LSS) are presented. The advent of the Shuttle will allow deployment of larger antennas with much larger gain sizes, noting new applications in communications, radiometry, and radar in frequencies from 0.24 to 14 GHz. Applications in multi-beam communication which can hold spot sizes on the ground down to 30 miles in diameter, new applications of the large aperture radar antenna, and estimates of soil moisture by the microwave radiometer are discussed. The Solar Power Satellite consisting of a large solar collector orbiting the earth at geosynchronous altitude over the equator which requires ability to construct LSS in space is described, noting the design of solar cells and materials of construction, including graphite composites and aluminum alloys. Space construction procedures and equipment are considered, noting that the most likely procedure would deliver the subsystems to orbit separately, and then construct the spacecraft on-orbit and assemble the satellite. A.T.

A79-53405 **Multi-cells satellite for the communications of year 2000.** E. Golden and J. Dilly (Matra, S.A., Paris, France). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-301*. 14 p.

An efficient, large communications satellite concept for the year 2000 is presented. Attention is given to the payload description, satellite assembly process, and transfer into geostationary orbit. Also discussed are the major characteristics of a typical multi-cells satellite including typical mission, system and satellite main characteristics, and assembly and launching. It is concluded that the total traffic of 100 Gb/s represents the equivalent of 3,125,000 telephony channels (32 kb/s delta modulation), 100 or 150 times more than the traffic of the largest satellite launched in the next 2 or 3 years. M.E.P.

A79-53406 * **The critical satellite technical issues of future pervasive broadband low-cost communication networks.** R. L. Harvey (MIT, Lincoln Laboratory, Lexington, Mass.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-302*. 21 p. 28 refs. Contract No. NAS5-25091.

The critical technical issues of signal waveform design, projected spacecraft technology, satellite launch options, and satellite cost are discussed for future pervasive broadband communication networks. With DPCM video signal encoding, 32 Mb/s user-to-user data rate per channel, 10% overhead, two orthogonal polarizations, and crosstalk loss limited to 1 dB, TFM permits about 75 channels/GHz of frequency allocation. The BOM (beginning of mission) weight and power of a baseline 400-channel multibeam satellite is about 1800 kg and 5000 W. Each 35 Mb/s channel can support 1 to 10 video channels. The weight and power estimates assume hardened digital logic, composite materials for a multibeam antenna structure, high-efficiency solar cells, batteries, and amplifiers. Based on a cost model for large communication satellites, the total space segment cost of two active satellites and one spare would be about $485 M. V.T.

A79-53409 **Trends in the design of future communications satellite systems.** H. Hartbaum (Telefunken AG, Backnang, West Germany), P. Hartl (Berlin, Technische Universität, Berlin, West Germany), and H. Treytl (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Cologne, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-307*. 34 p. 12 refs.

The present discussion indicates that the trends in the design of satellite communications in the immediate future point to a considerable increase in the number of satellites of moderate size, optimized to satisfy imminent communications needs. In industrialized countries, present demand is primarily for digital data transfer, computer interconnection, and business communications. In developing countries, emphasis will be on national and regional telephony networks designed to improve the basic communication infrastructure. In the long-term international coordination of orbit and spectrum allocations, introduction of (spectrum-conserving) higher frequency bands and large communication platforms is to be expected. Some current contributions to these developments are noted, particularly with respect to high-power TWTs in the 12 to 20 GHz range. V.P.

A79-53433 **Employment of large structure communications satellites for emergency calls.** G. Landauer and E. Messerschmid (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Institut für Nachrichtentechnik, Oberpfaffenhofen, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-A-34*. 14 p. 21 refs.

The application of large antenna structures for communication satellites reduces the transmitter equipment of distress and emergency call systems. The transmitter weight is minimum for emergency transmission around L-band frequencies. For simple emergency messages (100 bps) and speech transmissions (10,000 bps) and antenna diameters larger than few meters, transmitters can be made portable. Large space antennas together with such techniques as electronically switched multibeam antennas and efficient multiple access systems make it possible the frequency reuse based on spotbeam concept. V.T.

N79-22125*# National Aeronautics and Space Administration, Washington, D. C.
[SOME ACTIVITIES AND VEHICLE CONCEPTS ENVISIONED FOR FUTURE EARTH ORBITAL MISSIONS]
Bobby G. Noblitt *In* Von Karman Inst. for Fluid Dyn. Technol. of Space Shuttle Vehicles, Vol. 1 1970 24 p

Avail: NTIS HC A25/MF A01 CSCL 22B

Mission requirements, payloads and vehicles are discussed with regard to their mutual interaction. G.Y.

N79-22174*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
SYNCHRONOUS ORBIT POWER TECHNOLOGY NEEDS
Luther W. Slifer, Jr. and W. J. Billerbeck (COMSAT Labs., Clarksburg, Md.) Apr. 1979 36 p refs
(NASA-TM-80280) Avail: NTIS HC A03/MF A01 CSCL 22A

The needs are defined for future geosynchronous orbit spacecraft power subsystem components, including power generation, energy storage, and power processing. A review of the rapid expansion of the satellite communications field provides a basis for projection into the future. Three projected models, a mission model, an orbit transfer vehicle model, and a mass model for power subsystem components are used to define power requirements and mass limitations for future spacecraft. Based upon these three models, the power subsystems for a 10 kw, 10 year life, dedicated spacecraft and for a 20 kw, 20 year life, multi-mission platform are analyzed in further detail to establish power density requirements for the generation, storage and processing components of power subsystems as related to orbit transfer vehicle capabilities. Comparison of these requirements to state of the art design values shows that major improvements, by a factor of 2 or more, are needed to accomplish the near term missions. However, with the advent of large transfer vehicles, these requirements are significantly reduced, leaving the long lifetime requirement, associated with reliability and/or

refurbishment, as the primary development need. A few technology advances, currently under development, are noted with regard to their impacts on future capability. L.S.

N79-22191*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
RESULTS FROM SYMPOSIUM ON FUTURE ORBITAL POWER SYSTEMS TECHNOLOGY REQUIREMENTS
Sol Gorland 1979 8 p refs To be presented at the 14th Intersoc. Energy Conversion Eng. Conf., Boston, 5-10 Aug. 1979; sponsored by the Am. Chem. Soc.
(NASA-TM-79125; E-9961) Avail: NTIS HC A02/MF A01 CSCL 10B

The technology requirements for future orbital power systems were reviewed. Workshops were held in 10 technology disciplines to discuss technology deficiencies, adequacy of current programs to resolve those deficiencies and recommendations for tasks that might reduce the testing and risks involved in future orbital energy systems. Those recommendations are summarized. J.M.S.

N79-23126*# General Electric Co., Philadelphia, Pa. Space Div.
MISSION SPECIFICATION FOR THREE GENERIC MISSION CLASSES Final Report
May 1979 154 p refs
(Contract NAS1-15642)
(NASA-CR-159048) Avail: NTIS HC A08/MF A01 CSCL 22A

Mission specifications for three generic mission classes are generated to provide a baseline for definition and analysis of data acquisition platform system concepts. The mission specifications define compatible groupings of sensors that satisfy specific earth resources and environmental mission objectives. The driving force behind the definition of sensor groupings is mission need; platform and space transportation system constraints are of secondary importance. The three generic mission classes are: (1) low earth orbit sun-synchronous; (2) geosynchronous; and (3) non-sun-synchronous, nongeosynchronous. These missions are chosen to provide a variety of sensor complements and implementation concepts. Each mission specification relates mission categories, mission objectives, measured parameters, and candidate sensors to orbits and coverage, operations compatibility, and platform fleet size. Author

N79-27376# Thomson-CSF, Meudon-la-Foret (France). Dept. Espace-Satellites.
FEASIBILITY STUDY FOR A SATELLITE FREQUENCY MODULATED RADIO COMMUNICATION SYSTEM Final Report [ETUDE DE FAISABILITE D'UN SYSTEME DE RADIO-DIFFUSION SONORE A MODULATION DE FREQUENCE PAR SATELLITE, VOLUME I]
V. Biggi, B. VidalSaint Andre, P. MacNamara (Telecommun. Ltd), and F. Horgan (Telecommun. Ltd) Oct. 1978 148 p Partly in FRENCH and ENGLISH 2 Vol.
(Contract ESA-3208/77-F-HGE(SC))
(ESA-CR(P)-1151-Vol-1) Avail: NTIS HC A07/MF A01

The final report on the feasibility study for a satellite frequency modulated radio communication system is presented. The main subjects covered are the ground link (antenna gain, attenution effects, multipath problems, etc.), the space link (power stage, multiplexing, large orbital antennas), and the parametric study of space to ground communication (industrial noise, wave polarization, optimal frequency, transmitting, power, etc.). The system is reported feasible for national communication purposes and is more economic for low latitude countries than others. The choice of the 1 GHz frequency for the space to ground link is confirmed. Author (ESA)

N79-30266*# Rockwell International Corp., Downey, Cali Satellite Systems Div.
SPACE CONSTRUCTION SYSTEM ANALYSIS. PART 1 EXECUTIVE SUMMARY Final Report
Jun. 1979 295 p
(Contract NAS9-15718)
(NASA-CR-160295; SSD-79-0123) Avail: NTI HC A13/MF A01 CSCL 22A

System analysis studies of space construction projects primarily dealing with areas of space construction support services construction facilities, orbit altitude, and orbit transfer ar presented. R.E.S

N79-30268*# Rockwell International Corp., Downey, Calif Satellite Systems Div.
SPACE CONSTRUCTION DATA BASE
Jun. 1979 430 p refs
(Contract NAS9-15718)
(NASA-CR-160297; SSD-79-0125) Avail: NTIS HC A19/MF A01 CSCL 22A

Construction of large systems in space is a technolog requiring the development of construction methods to deploy assemble, and fabricate the elements comprising such systems A construction method is comprised of all essential function and operations and related support equipment necessary to accomplish a specific construction task in a particular way. The data base objective is to provide to the designers of large space systems a compendium of the various space construction methods which could have application to their projects. G.Y

N79-30269*# Rockwell International Corp., Downey, Calif Space Div.
SPACE CONSTRUCTION SYSTEM ANALYSIS. PART 1: EXECUTIVE SUMMARY. SPECIAL EMPHASIS STUDIES Final Report
Jun. 1979 186 p ref
(Contract NAS9-15718)
(NASA-CR-160298; SSD-79-0126) Avail: NTIS HC A09/MF A01 CSCL 22A

Generic concepts were analyzed to determine: (1) the maximum size of a deployable solar array which might be packaged into a single orbit payload bay; (2) the optimal overall shape of a large erectable structure for large satellite projects; (3) the optimization of electronic communication with emphasis on the number of antennas and their diameters; and (4) the number of beams, traffic growth, and projections and frequencies were found feasible to package a deployable solar array which could generate over 250 kilowatts of electrical power. Also, it was found that the linear-shaped erectable structure is better for ease of construction and installation of systems, and compares favorably on several other counts. The study of electronic communication technology indicated that proliferation of individual satellites will crowd the spectrum by the early 1990's, so that there will be a strong tendency toward a small number of communications platforms over the continental U.S.A. with many antennas and multiple spot beams. A.R.H

N79-30748# British Aerospace Dynamics Group, Bristol (England).
A STUDY ON SOLAR ARRAYS FOR PROGRAMMES LEADING FROM THE EXTENSION OF SPACELAB TOWARDS SPACE PLATFORMS
P. R. C. Gillett *In* ESA Photovoltaic Generators in Space Nov. 1978 p 119-129 refs Sponsored by ESA

Avail: NTIS HC A15/MF A01

A review of a mission scenario cavering the period from 1982 to the end of the century is presented, including some

preliminary solar array concepts. These concepts range from the augmentation of Spacelab by 6 kW arrays through Power Module and Space Platform arrays along with Pilot Power Plants, to a brief examination of 10 GW Space Solar Power Stations. The second phase of the study concentrates on concepts for a 50 kW Orbiter mounted array, a 55 kW Power Module array, and two types of 2 50 kW Space Platform arrays; these representing items of likely interest for European contributions to the near and medium term programs. Finally, an outline strategy for the implementation of these arrays is considered. Author (ESA)

N79-30879*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
PLATFORMS IN SPACE: EVOLUTIONARY TRENDS
John M. Butler, Jr. *In its* Proc.: Workshop on the Need for Lightning Observations from Space Jul. 1979 p 159-182

Avail: NTIS HC A12/MF A01 CSCL 22A

The problem of physical crowding and the proliferation of separate communication links and ground support systems for multiple free-flying satellites can be overcome by using space platforms and multiplexing the data streams. Pertinent features of the space shuttle orbiter payloads, the solar power satellite, and geostationary and geosynchronous platforms are discussed. Typical payload requirements data which are needed to allow meaningful study of payloads as candidates for platform implementation are cited and factors affecting the compatibility/grouping of payloads are outlined. A.R.H.

02
INTERACTIVE ANALYSIS AND DESIGN

Includes computerized technology design and development programs, dynamic analysis techniques, thermal modeling, and math modeling.

A79-34516 # **Stability analysis of a flexible spacecraft with a sampled-data attitude sensor.** S. Garg (Toronto, University, Toronto, Canada). *Journal of Guidance and Control,* vol. 2, May-June 1979, p. 169-172. 7 refs. Research supported by the National Research Council of Canada.

The pitch attitude control system for a flexible communications satellite is analyzed using sampled-data techniques. The sampling arises mainly from the use of discrete-time attitude measurement rather than from the digital controller implementation. It is found that Nyquist techniques lead to a relatively simple stability analysis that models the multirate sampling process with considerable fidelity, eliminating guesswork associated with equivalent delays. Controller modifications that improve stability are arrived at by this route. Finally, flexible-mode frequency and damping are varied to evaluate their influence on stability. There seems to exist a critical frequency at which stability margins are very small. Increasing the damping, predictably, improves matters. (Author)

A79-34732 # **Large Advanced Space System /LASS/ Computer Program.** A. F. Leondis (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 254-261. (AIAA 79-0904)

The LASS Computer Program was undertaken to provide a systems-oriented computer capability to rapidly synthesize, evaluate, derive performance characteristics and estimate costs for large advanced space satellites. The LASS program contains structure simulators that can detail all 6,030 struts of a 30-bay tetrahedral dish in minutes, or, if instructed to do so, will use the Tetrahedral Truss Simplification Analogy to model a dish of any size with any number of bays as a simpler structure. Rigid-body control equations are used to determine propellant and momentum exchange equipment masses. A number of load conditions are solved, including the dynamic responses due to an applied thrust as well as thermal loads and distortions. (Author)

A79-34740 # **Thermal control design analysis of an on-orbit assembly spacecraft.** R. F. O'Neill (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 324-332. (AIAA 79-0917)

Design requirements for large space structures such as the DOD/STS On-Orbit Assembly (OOA) spacecraft include stringent limitations on maximum allowable thermally induced structural deflections. The present paper describes a methodical, building-block approach to the thermal design analysis of the OOA spacecraft. A rationale is developed for selecting worst-case space environments and spacecraft orientations. The Vector Sweep computer program was used in computing shadowed incident heat flux histories for subsequent thermal analysis of the OOA spacecraft structures. The thermal response of typical structural elements is presented. B.J.

A79-37100 * # **Calculated scan characteristics of a large spherical reflector antenna.** P. K. Agrawal, W. F. Croswell (NASA, Langley Research Center, Hampton, Va.), and J. F. Kauffman (North Carolina State University, Raleigh, N.C.). *IEEE Transactions on Antennas and Propagation,* vol. AP-27, May 1979, p. 430, 431. 5 refs.

A previously published numerical method to calculate the radiation properties of parabolic reflectors has been modified to also include very large spherical reflectors. The method has been verified by comparing the calculated and the measured results for a 120-wavelength spherical reflector. (Author)

A79-38031 # **Thermal control of a spacecraft-deployable lattice boom.** J. J. Chapter (Martin Marietta Aerospace, Denver, Colo.). *American Institute of Aeronautics and Astronautics, Thermophysics Conference, 14th, Orlando, Fla., June 4-6, 1979, Paper 79-1047.* 8 p. 6 refs.

Long appendages or booms are required for spacecraft experiment probes, antennas, and gravity-gradient stabilization. Booms may extend hundreds of feet, and solar heating can result in thermal distortion and spacecraft attitude-control problems. The lattice boom analyzed in the present studies is constructed of graphite-epoxy longerons coupled by crossbow members with the assembly covered with a Kapton membrane. Analysis of the dynamic behavior of a boom is complex because it requires the coupling of thermal and mechanical phenomena. Two FORTRAN subroutines that together determine the temperature response of a graphite-epoxy/Kapton lattice boom have been developed for use in a dynamic-bending and thermal-distortion analysis computer program. Subroutine Q calculates the boom-incident solar-heat flux, whereas subroutine TEMP, a simplified thermal analyzer, calculates the boom temperature response. The validity of the thermal-analysis subroutines has been substantiated by correlation with thermal-vacuum test data. (Author)

A79-52555 # **Modal truncation for flexible spacecraft.** P. C. Hughes (Toronto, University, Toronto, Canada) and R. E. Skelton (Purdue University, West Layfayette, Ind.). *American Institute of Aeronautics and Astronautics, Guidance and Control Conference, Boulder, Colo., Aug. 6-8, 1979, Paper 79-1765.* 8 p. 14 refs.

A hierarchy of dynamical models is identified for large non-spinning flexible spacecraft. At each level, techniques are explained for reducing the order of the model before proceeding to the next level. These techniques have in common the presupposition that the model has at each state been expressed in terms of its natural modes, some of which can if necessary be deleted based on the evaluation of one or more of the quantitative criteria proposed. These criteria are based on insights from several different perspectives, including inertial completeness, frequency relationships, controllability and observability considerations, and the contributions of individual modes to a mission-dependent cost functional (modal cost analysis). With the aid of these criteria, many of the engineering judgements related to model order reduction can be made on a rigorous quantitive basis. (Author)

A79-52741 * **Derivation of the equations of motion for complex structures by symbolic manipulation.** A. L. Hale and L. Meirovitch (Virginia Polytechnic Institute and State University, Blacksburg, Va.). *Computers and Structures,* vol. 9, Dec. 1978, p. 639-649. 10 refs. Grant No. NsG-1114.

This paper outlines a computer program especially tailored to the task of deriving explicit equations of motion for structures with point-connected substructures. The special purpose program is written in FORTRAN and is designed for performing the specific algebraic operations encountered in the derivation of explicit equations of motion. The derivation is by the Lagrangian approach. Using an orderly kinematical procedure and a discretization and/or truncation scheme, it is possible to write the kinetic and potential energy of each substructure in a compact vector-matrix form. Then, if each element of the matrices and vectors encountered in the kinetic and potential energy is a known algebraic expression, the

computer program performs the necessary operations to evaluate the kinetic and potential energy of the system explicitly. Lagrange's equations for small motions about equilibrium can be deduced directly from the explicit form of the system kinetic and potential energy. (Author)

A79-53299 **Dynamic qualification of large space structures by means of modal coupling techniques.** A. Bertram (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Institut für Aeroelastik, Göttingen, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-107.* 12 p. 8 refs.

In this paper some problems are described which are expected to arise during dynamic qualification of future large space structures. It is shown that the methods applied today are no longer sufficient. As conclusion, the concept of a qualification procedure is proposed, which considers the phase of launching, as well as the phase of mission in orbit. (Author)

A79-53346 **General dynamics of a large class of flexible satellite systems.** K. W. Lips and V. J. Modi (British Columbia, University, Vancouver, Canada). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-192.* 16 p. National Research Council of Canada Grant No. A-2181.

The paper presents a general formulation for librational dynamics of satellites with an arbitrary number, type and orientation of deploying flexible appendages. In particular, the case of beam-type flexible appendages deploying from a satellite in an arbitrary orbit is considered. The governing nonlinear, nonautonomous and coupled equations for vibration of the appendages and libration of the satellite are integrated numerically. Several cases of practical importance are considered making the system progressively more general and hence complex: (1) planar case representing pitch and appendage oscillations in the orbital plane; (2) general attitude motion with planar vibrations of flexible members; and (3) above two cases together with the out-of-plane component of vibrations. Results show that under critical combinations of the system parameters the combined effect of flexibility and deployment can be substantial. (Author)

N79-22178*# Aerojet Electrosystems Co., Azusa, Calif.
SPACE STATION THERMAL CONTROL SURFACES Final Report
C. R. Maag, J. M. Millard, J. A. Jeffery, and R. R. Scott Apr. 1979 387 p refs
(Contract NAS8-32637)
(NASA-CR-161217; Rept-5836) Avail: NTIS HC A17/MF A01 CSCL 22B

Mission planning documents were used to analyze the radiator design and thermal control surface requirements for both space station and 25-kW power module, to analyze the missions, and to determine the thermal control technology needed to satisfy both sets of requirements. Parameters such as thermal control coating degradation, vehicle attitude, self eclipsing, variation in solar constant, albedo, and Earth emission are considered. Four computer programs were developed which provide a preliminary design and evaluation tool for active radiator systems in LEO and GEO. Two programs were developed as general programs for space station analysis. Both types of programs find the radiator-flow solution and evaluate external heat loads in the same way. Fortran listings are included. A.R.H.

N79-23128*# Cincinnati Univ., Ohio. Dept. of Aerospace Engineering and Applied Mathematics.
GEOMETRIC MODEL AND ANALYSIS OF ROD-LIKE LARGE SPACE STRUCTURES
A. H. Nayfeh and M. S. Hefney [1978] 64 p refs
(Grant NsG-1185)
(NASA-CR-158509) Avail: NTIS HC A04/MF A01 CSCL 22B

The application of geometrical schemes to large sphere antenna reflectors was investigated. The purpose of these studies is to determine the shape and size of flat segmented surfaces which approximate general shells of revolution and in particular spherical and paraboloidal reflective surfaces. The extensive mathematical and computational geometry analyses of the reflector resulted in the development of a general purpose computer program. This program is capable of generating the complete design parameters of the dish and can meet stringent accuracy requirements. The computer program also includes a graphical self contained subroutine which graphically displays the required design. G.Y.

N79-24027*# Grumman Aerospace Corp., Bethpage, N.Y.
ENVIRONMENTAL INTERACTION IMPLICATIONS FOR LARGE SPACE SYSTEMS
E. Miller, W. Fischbein, M. C. Stauber, and P. K. Suh *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 388-407
Avail: NTIS HC A99/MF A01 CSCL 22B

Large Space Systems (LSS) comprise a new class of spacecraft, the design and performance of which may be seriously affected by a variety of environmental interactions. The special concerns associated with spacecraft charging and plasma interactions from the LSS designer's viewpoint are addressed. Survivability of these systems under combined solar U.V., particle radiation and repeated electrical discharges is of primary importance. Additional questions regard the character of electrical discharges over very large areas, the effects of high current/voltage systems and magnitude of induced structural disturbances. A concept is described for a large scale experiment platform. G.Y

N79-33500*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
LOAD CONCENTRATION DUE TO MISSING MEMBERS IN PLANAR FACES OF A LARGE SPACE TRUSS
Joseph E. Waltz Washington Oct. 1979 39 p refs
(NASA-TP-1522; L-12872) Avail: NTIS HC A03/MF A01 CSCL 20K

A large space structure with members missing was investigated using a finite element analysis. The particular structural configuration was the tetrahedral truss, with attention restricted to one of its planar faces. Initially the finite element model of a complete face was verified by comparing it with known results for some basic loadings. Then an analysis was made of the structure with members near the center removed. Some calculations were made on the influence of the mesh size of a structure containing a hexagonal hole, and an analysis was also made of a structure with a rigid hexagonal insert. In general, load concentration effects in these trusses were significantly lower than classical stress concentration effects in an infinitely wide isotropic plate with a circular rigid inclusion, although larger effects were obtained when a hole extended over several rings of elements. Author

03
STRUCTURAL CONCEPTS

Includes erectable structures (joints, struts, and columns), deployable platforms and booms, solar sail, deployable reflectors, space fabrication techniques and protrusion processing.

A79-34745 * # **Expandable modules for large space structures.** J. M. Hedgepeth (Ast o Research Corp., Carpinteria, Calif.) and M. M. Mikulas (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 375-379. Contract No. NAS1-14887. (AIAA 79-0924)

There is a need for means to construct large complex structures without having to spend a large amount of time for assembly. One approach to meeting this requirement is to erect the overall structure using highly efficient structural modules. The individual modules can then be packaged for launch, so as to utilize the volume of the Shuttle properly, and then expanded in orbit. The present paper describes several types of such modules that have been designed and tested. B.J.

A79-34746 # **Large solid deployable reflector.** W. B. Palmer and M. M. Giebler (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 380-389. (AIAA 79-0925)

A deployment concept has been developed for large, solid surface, high accuracy antenna reflectors. The design consists of a variable number of deployable panels hinged from a fixed center section. The panels are permanently hinged to each other to minimize thermal distortion and to ensure accuracy upon deployment. A maximum error of .005 inch 1/2 path length RMS has been predicted for a 16 ft reflector, due to both thermal distortion and manufacturing tolerances. Analysis of a 24 ft reflector by computer graphics and finite element modeling has included calculation of stowed and deployed deflections and natural frequencies. A restowing mechanism and contour measurement techniques have also been examined. (Author)

A79-34748 * # **Deployable multi-payload platform.** L. M. Jenkins (NASA, Johnson Space Center, Spacecraft Design Div., Houston, Tex.) and F. C. Runge (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 400-408. (AIAA 79-0928)

Many space payloads with similar mission requirements can be grouped and accommodated on an orbiting platform which provides high-capacity, centralized services. Various concepts for such a platform were devised and evaluated to identify optimal features, interface prospects and areas of technological challenge. Guidelines included minimum and augmented mission models for science and applications payloads for the 1985-90 time period, minimum extension of the Orbiter capability, maximum use of the Orbiter remote manipulator system and capitalization on EVA where applicable. Deployable structures were employed to provide spacious payload berthing on a platform which can be highly-compacted for shuttle delivery. (Author)

A79-34749 * # **Erectable platform for science and applications payloads circa 1985.** F. A. Zylius (Rockwell International Corp., Satellite Systems Div., Pittsburgh, Pa.) and L. Keafer (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 409-416. (AIAA 79-0931)

A program involving the development of one or more free-flying platforms for earth orbit to provide accommodations and operational services to space science and applications payloads is described. An overview is presented of studies carried out to select a specific platform and utilities module concept, its subsystems, and the means by which services are supplied to dependent science and applications mission equipment. Some examples are given of candidate research and technology programs that support development of the platform system. B.J.

A79-34750 * # **Deployable antenna technology development for the Large Space Systems Technology program.** R. E. Freeland (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.) and T. G. Campbell (NASA, Langley Research Center, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 417-428. 21 refs. Contract No. NAS7-100. (AIAA 79-0932)

The critical technologies associated with the development of deployable reflector antenna technology for the LSST program will be derived from NASA mission models and the subsequent requirements will be related to the classes of missions involved. The approach formulated for the development of reflector technology is based on the development of specific reflector concepts that have been identified as leading candidates for future applications. The development approach will be augmented by supporting technology disciplines such as controls, materials, electromagnetic analysis, as well as the capability of analytically predicting the overall performance of the large space system. B.J.

A79-34751 # **Post-fabrication contour adjustment for precision parabolic reflectors.** J. S. Archer (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 429-437. 5 refs. (AIAA 79-0933)

Post-fabrication adjustment is an effective procedure for attaining high precision in the fabrication and assembly of parabolic reflectors. This technique has been applied to fixed solid surface, deployable rib-mesh and deployable solid surface reflectors. Contour adjustment to minimize the contour rms can be performed at any stage of the fabrication, subsystem integration, deployment and assembly in low earth orbit (LEO) or during free-flight on-orbit operational checkout. When coupled with the use of graphite epoxy construction, this capability could lead to the development of reflectors capable of operating at frequencies from 100 to 1000 GHz. (Author)

A79-34753 # **Maypole /Hoop/Column/ deployable reflector concept development for 30 to 100 meter antenna.** B. C. Tankersley (Harris Corp., Melbourne, Fla.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 446-458. (AIAA 79-0935)

The hoop/column, a tensioned structure of the maypole class, is intended for applications in the 30-100 meter diameter range. Pack-

aging constraints consistent with the Space Shuttle transportation capability necessitate a unique concept to deploy and stabilize the large mesh reflective surface. A NASA LaRC sponsored program is currently underway to develop this concept through preliminary design. B.J.

A79-34756 # **An approach toward the design of large diameter offset-fed antennas.** A. A. Woods, Jr., and W. D. Wade (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 475-480. (AIAA 79-0938)

A desire for maximum efficiency in space antennas is placing emphasis on the application of offset fed antennas. Lockheed Missiles and Space Company has been investigating the application of the wrap-rib design in the offset geometry antenna configuration. The basic technology developed over the previous 15 years on deployable antennas is directly applicable with relatively minor modifications required in the area of rib, or surface support, manufacturing and constraints on feed tower/reflector support booms. This basic wrap-rib design approach for large apertures as applied to both the symmetric and offset configurations is discussed and performance/growth capability presented. (Author)

A79-34758 # **Large multibeam space antennas.** P. Foldes (General Electric Co., Space Div., Valley Forge, Pa.) and M. W. Dienemann (General Electric Co., Re-Entry and Environmental Systems Div., Philadelphia, Pa.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 493-502. (AIAA 79-0942)

Large multibeam space antennas requiring sophisticated beam-forming networks, accurate figure control, and reconfigurability to accommodate changing data flow and provide beam control are envisaged as commonplace in the next 10 years. It is shown that these multibeam antenna systems require technology development in the areas of large offset-fed parabolic reflectors to reduce beam blockage, accurate reflector surface contours to maintain beam isolation, low thermal gradient control to reduce defocusing errors, and active real time beam shape control. B.J.

A79-46062 # **Optimization of triangular laced truss columns with tubular compression members for space application.** C. H. Yoo (Marquette University, Milwaukee, Wis.). *AIAA Journal,* vol. 17, Aug. 1979, p. 921-924. 8 refs.

Minimum-weight optimization procedures are considered for a tubular laced column, one of the most weight-efficient components of large space structures. The procedures are based on designing for a column with initial imperfections. The optimum design procedures are applied to the example of a graphite/epoxy column 10-500 m long and subjected to loading from 1000 N to 25,000 N with initial imperfection ratios ranging from 0-0.004. B.J.

A79-53261 **Solar thermal aerostat research station /STARS/.** E. C. Okress and R. K. Soberman (Franklin Institute, Franklin Research Center, Philadelphia, Pa.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-35.* 12 p. 14 refs.

The paper introduces the concept of a large, constant volume, solar powered, warm air, spherical rigid navigable aerostat able to remain aloft in the stratosphere for many years. Equipped with compressed stratospheric air for energy storage, it will be capable of performing, on a 24-hour basis, a wide variety of missions, including surveillance, solar energy generation and radiation or particle beam transmission to the surface, environmental monitoring, local weather modifications, long-range communications and microwave power relay, nighttime target illumination, weapons platform of high energy requirements, platform for aircraft launch and recovery, platform for space hardware and reusable spacecraft catapult launching, etc. Most, if not all, of these numerous missions may be conducted simultaneously, due to the unprecedented lift capability of the proposed stratocraft. With solar energized compressed air and electric thrusters, it will be capable of 24 hours navigation and hovering in the stratosphere in most regions about the earth, and throughout the year, for many (e.g., about 10) years. (Author)

A79-53298 * **Construction of large space structures.** J. F. Garibotti, A. J. Cwiertny, Jr., R. Johnson, Jr. (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.), and T. J. Dunn (NASA, Johnson Space Center, Houston, Tex.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-106.* 15 p. 5 refs.

The paper examines a construction capability to build large structures in space, its use in conjunction with the Shuttle Orbiter and a large Space Construction Base, and its relationship to system performance and cost. The geodetic beam design using a tetrahedral truss structure and reinforced plastics and its structural analysis, tests of demonstration cylinders, and preliminary machine design are discussed. The geodetic structure is shown to have high buckling stability, low thermal distortion, high stiffness, and its simple shape permits high-production-rate automatic fabrication. The geodetic beam fabrication machine which will automatically fabricate cylindrical beams in space from earth-prefabricated rods, and on-orbit beam and platform fabrication are described. Preliminary results of system performance and cost studies indicate that on-orbit fabrication using a small geodetic beam machine can be economically superior to the deployable and erectable modes of construction for many near term applications. A.T.

A79-53360 **Large geostationary communications platform.** W. L. Morgan (COMSAT Laboratories, Clarksburg, Md.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-210.* 14 p. 9 refs. Research sponsored by the Communications Satellite Corp.

This paper reviews the large space structure concepts variously known as orbital antenna farms, geostationary platforms, or space stations. It does not advocate any one position, but provides a balanced overview of the present situation. As is typical of all new technologies, various approaches to such a large project are being considered, and their distinctive features are highlighted. This paper also estimates the communications satellite capacity which will be required by the year 2000. The various options available to the designer are reviewed in the following areas: low earth orbit operations, the ascent to the geostationary earth orbit, initial deployment on orbit, and the communications growth requirements. (Author)

A79-53361 **Lightweight deployable microwave satellite antennae - Need, concepts and related technology problems.** D. Fasold, L. Heichele, and W. Schaefer (Messerschmitt-Bölkow-Blohm GmbH, Ottobrunn, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-211.* 17 p. 13 refs. Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt Contract No. 01-TB-047-AK/RT/WRT-20.

Technology of a microwave satellite parabolic reflector antennae is examined. Microwave antennae with high pointing accuracy, high directivity and/or small beam width will be required for communication satellites of the second generation, and parabolic antennae with aperture diameters up to 30 microns fulfill these RF-requirements.

Weight and size constraints of spacecraft structures will require light-weight deployable antennae, illustrated by petal and mesh reflector concepts. Selection criteria, most suitable reflector concepts, the mesh manufacturing technology, and measurement of mesh RF-properties are discussed. Mesh adjustment technology, accurate CFRP-panel manufacturing, and deployment and locking devices of very high accuracy are shown. The deployable mesh reflector appears most promising, and reflection measurements of mesh samples at 12 and 18 GHz are analyzed. A.T.

A79-53404 * **Communication architecture for large geostationary platforms.** F. E. Bond (Aerospace Corp., El Segundo, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-300.* 17 p. 6 refs. Contract No. NAS8-32281.

Large platforms have been proposed for supporting multipurpose communication payloads to exploit economy of scale, reduce congestion in the geostationary orbit, provide interconnectivity between diverse earth stations, and obtain significant frequency reuse with large multibeam antennas. This paper addresses a specific system design, starting with traffic projections in the next two decades and discussing tradeoffs and design approaches for major components including: antennas, transponders, and switches. Other issues explored are selection of frequency bands, modulation, multiple access, switching methods, and techniques for servicing areas with nonuniform traffic demands. Three-major services are considered: a high-volume trunking system, a direct-to-user system, and a broadcast system for video distribution and similar functions. Estimates of payload weight and d.c. power requirements are presented. Other subjects treated are: considerations of equipment layout for servicing by an orbit transfer vehicle, mechanical stability requirements for the large antennas, and reliability aspects of the large number of transponders employed. (Author)

N79-22563*# General Dynamics/Convair, San Diego, Calif.
DEVELOPMENT OF A BEAM BUILDER FOR AUTOMATIC FABRICATION OF LARGE COMPOSITE SPACE STRUCTURES
John G. Bodle *In* NASA. Johnson Space Center The 13th Aerospace Mech. Symp. 1979 p 293-304 ref

Avail: NTIS HC A13/MF A01 CSCL 22B

The composite material beam builder which will produce triangular beams from pre-consolidated graphite/glass/thermoplastic composite material through automated mechanical processes is presented, side member storage, feed and positioning, ultrasonic welding, and beam cutoff are formed. Each process lends itself to modular subsystem development. Initial development is concentrated on the key processes for roll forming and ultrasonic welding composite thermoplastic materials. The construction and test of an experimental roll forming machine and ultrasonic welding process control techniques are described. S.E.S.

N79-24066*# Boeing Aerospace Co., Seattle, Wash.
DESIGN FABRICATION AND TEST OF GRAPHITE/POLYIMIDE COMPOSITE JOINTS AND ATTACHMENTS FOR ADVANCED AEROSPACE VEHICLES Quarterly Technical Progress Report, 15 Jan. 1979
15 Apr. 1979 41 p refs
(Contract NAS1-15644)
(NASA-CR-159080; QTPR-1) Avail: NTIS HC A03/MF A01 CSCL 11D

Graphite/polyimide (Gr/PI) bolted and bonded joints were investigated. Possible failure modes and the design loads for the four generic joint types are discussed. Preliminary sizing of a type 1 joint, bonded and bolted configuration is described, including assumptions regarding material properties and sizing methodology. A general purpose finite element computer code is described that was formulated to analyze single and double lap joints, with and without tapered adherends, and with user-controlled variable element size arrangements. An initial order of Celion 6000/PMR-15 prepreg was received and characterized. J.M.S.

N79-25425*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
FOLDABLE BEAM Patent Application
John M. Hedgepeth (Astro Research Corp., Carpinteria, Calif.), John V. Coyner (Astro Research Corp., Carpinteria, Calif.), and Robert F. Crawford, inventors (to NASA) (Astro Research Corp., Carpinteria, Calif.) Filed 23 Feb. 1979 15 p Sponsored by NASA
(NASA-Case-LAR-12077-1; US-Patent-Appl-SN-014663) Avail: NTIS HC A02/MF A01 CSCL 20K

The invention is used in cases where a conventional solid beam is unsuitable, specifically where transportation to the use site requires a more lightweight or compact structure. Ease of deployment is another object. Construction of antennae or platforms in outer space is such a case. The novelty of the invention lies in the use of hinged segments in conjunction with cables, whereby a collapsed assembly of lightweight tublar struts may be readily deployed simply by applying tension to the cables, and just as easily stowed by loosening the cables.

Official Gazette of the U.S. Patent and Trademark Office

N79-29203*# General Dynamics/Convair, San Diego, Calif.
SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS), PART 3. VOLUME 2: STUDY RESULTS Final Report
29 Jun. 1979 309 p refs
(Contract NAS9-15310)
(NASA-CR-160288; CASD-ASP78-016-Vol-2) Avail: NTIS HC A14/MF A01 CSCL 22A

The detailed results of all part 3 study tasks are presented. Selected analysis was performed on the beam builder conceptual design. The functions of the beam builder and a ground test beam builder were defined. Jig and fixture concepts were developed and the developmental plans of the beam builder were expounded. R.E.S.

N79-29213*# Grumman Aerospace Corp., Bethpage, N.Y.
SPACE FABRICATION DEMONSTRATION SYSTEM, TECHNICAL VOLUME Final Report
15 Mar. 1979 117 p
(Contract NAS8-32472)
(NASA-CR-161286; NSS-SFDS-RP013) Avail: NTIS HC A06/MF A01 CSCL 22A

The automatic beam builder ABB was developed, fabricated, and demonstrated within the established contract cost and schedule constraints. The ABB demonstrated the feasibility of: producing lightweight beams automatically within the required rate of 1 to 5 ft of completed beam per minute and producing structurally sound beams with axial design load of 5538 N based on the Grumman photovoltaic satellite solar power system design reference structure. Author

N79-29214*# Grumman Aerospace Corp., Bethpage, N.Y.
SPACE FABRICATION DEMONSTRATION SYSTEM: EXECUTIVE SUMMARY Final Report
15 Mar. 1979 35 p
(Contract NAS8-32472)
(NASA-CR-161287; NSS-SFDS-RP013) Avail: NTIS HC A03/MF A01 CSCL 22A

The results of analysis and tests conducted to define the basic 1-m beam configuration required, and the design, development, fabrication, and verification tests of the machine required to automatically produce these beams are presented. M.M.M.

03 STRUCTURAL CONCEPTS

N79-30584# Construcciones Aeronauticas S.A., Madrid (Spain). Space Div.
STUDY OF HIGH STABILITY STRUCTURAL SYSTEMS: PRE-PHASE A Final Report
Paris ESA 29 Sep. 1978 160 p refs
(Contract ESTEC-3398/77/NL-PP(SC))
(DT-HSS-5; ESA-CR(P)-1164) Avail: NTIS HC A08/MF A01

The feasibility of large, high stability, flat, deployable antennas for earth resources observation was studied. A synthetic aperture radar antenna, 10 meters long by 1 meter wide, was taken as a representative structure of this type. Requirement definitions, interface design constraints, and a trade-off analysis of different solutions were considered. Possible design concepts and an analysis of the thermal loads were studied. Due to the different possibilities of the design configurations, strongly depending on some not well defined interfaces during development, the mechanical bahavior of the presented designs are omitted or studied in a simplified manner. Author (ESA)

N79-31314# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
DEVELOPMENT OF A MOVABLE, THERMALLY CONDUCTING JOINT FOR APPLICATION TO DEPLOYABLE RADIATORS
B. Hinderer and C. J. Savage (ESTEC) *In* ESA Spacecraft Thermal and Environ. Control Systems Oct. 1978 p 449-452

Avail: NTIS HC A99/MF A01

The development of a thermal joint concept for radial heat transfer from a fixed feeder to a deployable radiator is presented. A critical comparison of several imaginable techniques considered from thermal and mechanical points of view shows that most favorable results with regard to thermal efficiency and low deployment torques can be expected using a mixture of conductive grease and silver powder as interface filler between feeder and rotor. The design of a technological model based on these investigations is described and the results of a thermal-vacuum-test are given. Radial temperature drops and measured torques proved to be acceptable within the required ranges of temperature and radial heat flux density. Author (ESA)

04
CONTROL SYSTEMS

Includes new attitude and control techniques, improved surface accuracy measurement and control techniques.

A79-34523 # **Direct velocity feedback control of large space structures.** M. J. Balas (Bolt Beranek and Newman, Inc., Cambridge, Mass.). *Journal of Guidance and Control,* vol. 2, May-June 1979, p. 252, 253. 5 refs.

A method, called direct velocity feedback, for active vibration suppression of large space structures is presented. Output signals from velocity sensors are electronically multiplied by gains and these signals are directly fed back to collocated force actuators. The DVFB controller cannot destabilize the system provided that (1) the number of collocated force actuators is equal to the number of velocity sensors, (2) the feedback gain matrix is nonnegative definite, and (3) if zero frequency modes exist, the actuators must maintain constant energy in these modes. A large symmetric eigenvalue calculation is set up but not carried through for determining the actual pole locations of the closed-loop system. P.T.H.

A79-34743 * # **Electrostatically formed antennas.** D. J. Mihora and P. J. Redmond (General Research Corp., Santa Barbara, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 354-365. 7 refs. Contract No. NAS1-15548; Grant No. DASG60-77-C-0123. (AIAA 79-0922)

The electrostatically controlled membrane mirror (ECMM) is a way to achieve large, very light reflectors for radar, radio astronomy, radiometry, and optical devices. The concept is that of using electrostatic forces to tension a thin conducting membrane and to maintain it in a precision antenna shape. The ECMM is an adaptive structure which maintains surface quality despite errors in construction, irregularities of materials, solar heating, and onboard disturbances. The combination of high gain and low mass makes the ECMM ideally suited for space applications. B.J.

A79-34744 * # **The dual-momentum control device for large space systems.** R. C. Montgomery (NASA, Langley Research Center, Flight Dynamics and Control Div., Hampton, Va.) and C. R. Johnson, Jr. (NASA, Langley Research Center, Hampton; Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 366-374. 9 refs. (AIAA 79-0923)

The dual-momentum control device being studied for large spacecraft consists of two counter-rotating rings, each designated as an annular momentum control device (AMCD). For large rings, flexibility is appreciable and it becomes necessary to account for the distributed nature of the rings in the design of the magnetic bearing controllers. Also, ring behavior is unpredictably sensitive to ring temperature, spin rate, manufacturing imperfections, and other variables. For that reason, an adaptive control system is being sought for ring stabilization and maneuvering. This paper details an original adaptive control methodology for distributed parameter systems and illustrates this technique by application to AMCD stabilization. (Author)

A79-34747 # **Control of large space structures using equilibrium enforcing optimal control.** R. J. Benhabib and R. P. Iwens (TRW Control and Sensor Systems Laboratory, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 390-399. 11 refs. (AIAA 79-0927)

Weighting matrices in the performance index of a linear optimal regulator are selected so as to minimize the excitation of residual modes of large space structures. Even though this design technique is successful with respect to spillover, an extremely sensitive controller results which becomes unstable for small perturbations in the assumed frequencies of the controlled modes. It is shown how the sensitivity of the controller to modeling errors can be reduced. Finally, it is shown how stability theory developed for distributed control of large scale systems can be used to test the a priori stability of control systems for large space structures. B.J.

A79-34752 * # **A self pulsed laser ranging system under development at 'JPL'.** M. Berdahl (California Institute of Technology, Jet Propulsion Laboratory, Applied Mechanics Div., Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 438-445. 9 refs. Contract No. NAS7-100. (AIAA 79-0934)

The performance of large space deployable antenna reflectors to be used for broad-based communications systems is largely dependent on the accuracy with which the surface figure can be constructed and maintained. The paper examines various surface distortion tolerance and measurement requirements for various classes of communication antennas. Several surface measuring methods are described including a self-pulsed laser ranging system. B.J.

A79-34755 * # **Surface accuracy measurement system deployable reflector antennas.** R. S. Neiswander (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 467-474. Contract No. NAS1-15520. (AIAA 79-0937)

Conceptual optical sensor configurations for measuring the surface deformations of large, deployable space antennas are described. These antennas include precision deployable reflectors up to 30 meters diameter and 1000 GHz frequency and mesh deployable reflectors up to 100 meters diameter and 30 GHz frequency. For each representative antenna configuration, the surface deformation sensor provides continuous, real-time measurements at a sufficient number of sample points to be compatible with active surface control. Moreover, the sensor system does not interfere with the mechanical or microwave characteristics of either the antenna surface or the feed. For the applications considered, the sensor system consists of a central receiver ring containing six to ten long focal length, angle measuring instruments, each viewing a dedicated set of bright point targets at the antenna. The targets, either light emitting diodes or illuminated retroreflectors, are modulated to eliminate errors from spurious backgrounds. Very preliminary performance estimates indicate that the sensor system, using commerical grade components, can produce a 20th to a 30th wavelength accuracy (3 sigma). (Author)

A79-34763 * # **Nonreflective boundary control of a vibrating string.** A. K. Caglayan (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 535-539. 11 refs. Grant No. NsG-1527. (AIAA 79-0950)

One of the important applications in the developing Large Space Systems Technology will be the electrostatically controlled membrane mirror antenna. A high level of surface quality is achievable using electrostatically tensioned membranes in which surface accu-

racy is obtained through active control. Electrostatic actuators behind the membrane surface would provide a means of obtaining the prescribed surface shape and also be utilized to suppress the structural vibrations in the system. The surface quality, in this case, would be limited by the size, force field shape, and the number of the electrostatic actuators. An additional control capability is to introduce boundary control at the membrane perimeter. Using this additional control mechanism, structural vibrations can be absorbed at the boundary without being reflected back into the interior regions of the membrane antenna. In this paper, boundary control of a vibrating string is studied. For this system, a nonreflective boundary control is developed in which waves reaching the boundary are absorbed by the appropriate control movement of the boundary. The control is closed-loop and utilizes a single measurement close to the boundary. The closed-loop control is a delay of the measurement. The delay is determined by the velocity of wave propagation in the string and the location of the sensor. (Author)

A79-34765 # **Long interface docking for large space structure assembly.** R. B. Rice (Martin Marietta Aerospace, Denver, Colo.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 546-549. (AIAA 79-0954)

The control system and resultant dynamics for a large space structure during autonomous assembly is presented. Mission and system configurations are discussed in addition to details of reaction control system and dock servos. Simulation results are given for a representative structure showing convergence, damping characteristics, and flexible body mode effects for long interface docking in space. (Author)

A79-34766 * # **Stability and control of future spacecraft systems.** S. Z. Szirmay (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 550-557. (AIAA 79-0864)

A brief review is presented of some of the problem areas associated with large space structures and some of the approaches currently being taken to find solutions are discussed. Consideration is given to such areas as control system analysis, design and implementation, and those aspects of structural modeling related to control system design. B.J.

A79-34767 * # **Attitude control requirements for future space systems.** J. B. Dahlgren and R. S. Edmunds (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 558-562. (AIAA 79-0951)

Landsat-D and the Large Space Telescope represent current state-of-the-art systems with precise requirements placed on attitude control. Future systems for planetary stations, high precision earth monitoring and large precision deployable and erectable platforms project still more severe constraints and requirements on attitude control, including the requirement for many enabling and highly enhanced technologies beyond current state of the art. Two trend projections are identified for the areas of (1) precision pointing systems for earth orbiters and planetary spacecraft and (2) onboard high-capacity fast controllers for distributed control systems. B.J.

A79-36189 # **Attitude control by solar sailing - A promising experiment with OTS-2.** U. Renner (ESA, Communication Satellite Dept., Noordwijk, Netherlands). *ESA Journal,* vol. 3, no. 1, 1979, p. 35-40.

With solar arrays generally deformed by internal stresses, a spacecraft such as the geostationary OTS-2 communication satellite is subject to solar pressure torques. Consequently it is suggested to use solar pressure as a source of control torque for compensating a disturbance torque. In typical solar array maneuver one array continues to track the sun, while the other array drive is disabled until a predetermined array angle is reached. Then the array drive loop is re-enabled with the array reaching its normal position. According to the orbit test, the OTS-2 attitude was controlled entirely by solar sailing for almost six days while all the spacecraft's thrusters were disabled. Whereas the basic operating principles - step size, duty cycle and pointing accuracy - are comparable with those of a standard thruster control system, solar sailing has a number of advantages: saving of thrusters and fuel, inherent nutation damping and smooth operation throughout maneuvers. Potential disadvantages are: temporary reduction in solar-array power and increase in the acquisition duty of the solar-array drive. V.T.

A79-37287 **Observability measures and performance sensitivity in the model reduction problem.** R. E. Skelton (Purdue University, West Lafayette, Ind.). *International Journal of Control,* vol. 29, Apr. 1979, p. 541-556. 13 refs.

A model reduction problem (MRP) is related to the control problem by use of a 'model quality index' which measures the performance of the higher-order system when the control is based upon a lower-order model. By truncating modal coordinates which have smaller sensitivity to the model quality index a first approximation to the MRP is obtained. Another approximation to the MRP is obtained by truncation of modal coordinates which have smaller sensitivities to the first term in the model quality index, called the 'cost of information'. Several theorems relate the scalar measures of observability of each modal coordinate to the first-order sensitivity of the 'cost of information' and of the model quality index. A case study with a flexible spacecraft illustrates truncation on the basis of observability measures and controllability measures. (Author)

A79-41106 * # **The dual momentum control device for large space systems - An example of distributed system adaptive control.** R. C. Montgomery (NASA, Langley Research Center, Flight Dynamics and Control Div., Hampton, Va.) and C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Annual Asilomar Conference on Circuits, Systems, and Computers, 12th, Pacific Grove, Calif., November 6-8, 1978, Conference Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1979, p. 59-68. 5 refs.

One area in which large space systems require new technology is attitude control. The paper presents an adaptive control philosophy applicable to the control of distributed systems. An adaptive control system is described for stabilization of the flexible modes of a spinning ring. The system consists of a modal decomposition and identification subsystem, a gain adjustment subsystem, and a feedback control subsystem. Simulations are presented illustrating the adaptive capability of the system. The adaptive controller did produce stable results by quickly identifying the parameter differences and adjusting the feedback controller gains. S.D.

A79-41699 * # **Stability bounds for the control of large space structures.** S. M. Joshi (NASA, Langley Research Center, Hampton; Old Dominion University Research Foundation, Norfolk, Va.) and N. J. Groom (NASA, Langley Research Center, Hampton, Va.). *Journal of Guidance and Control,* vol. 2, July-Aug. 1979, p. 349-351. 7 refs.

Balas (1977) has discussed the stability problem of reduced-order regulators and estimators in terms of control and observation 'spillover'. The term 'control spillover' was used to define that part

of the feedback control which excites the uncontrolled (or residual) modes, and 'observation spillover' was used to define that part of the measurement which is contaminated by residual modes. In this paper, two sufficient conditions are derived via Lyapunov methods for asymptotic stability of large space structures using a class of reduced-order controllers. These conditions give allowable bounds on the spectral norms of control and observation spillover terms. The sufficient condition given by a specified inequality equation appears to be less conservative, and should be useful as a design tool for the control of large space structures. S.D.

A79-44413 **Guidance and control 1979; Proceedings of the Annual Rocky Mountain Conference, Keystone, Colo., February 24-28, 1979.** Conference sponsored by the American Astronautical Society. Edited by R. D. Culp (Colorado, University, Boulder, Colo.). San Diego, Calif., Univelt, Inc. (Advances in the Astronautical Sciences. Volume 39), 1979. 491 p. $31.25.

Satellite navigation and attitude control and determination, autonomous systems in space, the NASA approach to standardization, and deployment and retrieval of Shuttle-era payloads are studied. Autonomous attitude determination systems, inertial measurement unit redundancy management, the fault-tolerant spaceborne computer (FTSC), a description and comparison of the NASA standard computers, and the multimission modular spacecraft are considered. Attention is given to precision correlating tracking, requirements and opportunities for autonomous systems in space, spacecraft automated operations, the NASA multimission spacecraft modular attitude control system, and navigation and flight control in the inertial upper stage. V.T.

A79-45351 **Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers.** Conference sponsored by the American Institute of Aeronautics and Astronautics. New York, American Institute of Aeronautics and Astronautics, Inc., 1979. 707 p. $65.

Papers are presented on such topics as dual digital flight control redundancy management system development, fuel-conservative guidance system for powered-lift aircraft, laser gyros in precision spacecraft attitude determination systems, and guidance law design for tactical weapons with strapdown seekers. Also considered are optimization of earth sensor thresholding techniques, a structural model of the adaptive human pilot, a method for determining the performance of a precision inertial guidance system, and adaptive modal control of large flexible spacecraft. B.J.

A79-45380 * # **Control of large flexible space structures using pole placement design techniques.** Y. W. Wu, R. B. Rice (Martin Marietta Aerospace, Denver, Colo.), and J. N. Juang (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.; Martin Marietta Aerospace, Denver, Colo.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 321-328. 19 refs. (AIAA 79-1738)

A design approach via the pole placement techniques for the class of large flexible space structures is developed. The numerical problems in pole placement algorithm, arising from large dimension systems and the extremely low frequency eigenvalues which occur in large space structure models are examined. It shows these numerical difficulties may be overcome by properly selecting the sensor/actuator locations and introducing a frequency scaling scheme. The concepts of this paper are illustrated by some numerical studies on the linear feedback control design of a representative large spacecraft consisting of a small rigid core with ten radial booms (five booms 1000 ft long and five shorter booms 700 ft long) lying in a plane. (Author)

A79-45381 # **Attitude control of agile flexible spacecraft.** J. Y. L. Ho and H. A. Posnansky (Lockheed Missiles and Space Co., Inc., Guidance and Control Systems Dept., Sunnyvale, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 329-338. 5 refs. (AIAA 79-1739)

An advanced control for attitude control of agile flexible spacecraft is presented. Multiple sensors feedback information for both the equipment section and the flexible structure are used. A design procedure is outlined to determine controller gains by the pole placement method. Combination of outer loop feedback of attitude and rate and inner loop feedback of rate and acceleration is used. This advanced control design is applied to a digital multibody flexible spacecraft simulation program. Comparison with conventional control for response performance is made. The advanced control concept is very promising to meet the fast maneuvering and fine pointing requirements for the agile flexible spacecraft. (Author)

A79-45382 * # **Optimal local control of flexible structures.** D. B. Schaechter (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 339-344. 8 refs. Contract No. NAS7-100. (AIAA 79-1740)

The steady state solution of the linear quadratic optimal control problem with the constraint that only partial state information is available for feedback is derived. This development results in a systematic and computationally efficient approach for reducing the complexity of the control law for high order systems. Numerical examples and performance evaluation of (1) a simple fourth order system, and (2) a free-free flexible beam, are included. (Author)

A79-45383 # **A family of sensors for the sensing of the position and vibration of spacecraft structures.** R. H. Anderson, C. C. Huang, and N. E. Buholz (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 345-351. (AIAA 79-1741)

A family of laser heterodyne sensors is being developed for use in the active control of spacecraft structures. These sensors include an He-Ne distance measuring system for structures requiring accuracies to 0.1 mm and CO2 distance measuring system which will measure unambiguously down to 0.01 micron. Vibration sensors based on both He-Ne and CO2 laser are also being developed. All of these sensors have been breadboarded to verify performance and are in various stages of development directed toward prototype engineering models. B.J.

A79-45384 # **Orthogonal subspace reduction of optimal regulator order.** T. Coradetti (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 352-358. 14 refs. (AIAA 79-1742)

A large system may be considered as an assembly of subsystems occupying mutually orthogonal subspaces. Using this orthogonality, an algorithm is developed for the design of optimal low-order-state

feedback regulators which control a subsystem independently of the rest of the system. Conditions are stated under which a regulator can be constructed which has zero control spillover to states which are modeled but are not to be controlled. A comparison is made between this method of control spillover reduction and the method of forced singular perturbation. Results are applicable to the study of structural vibration in large spacecraft. B.J.

A79-45405 # **Active control of certain flexible systems using distributed and boundary control.** A. K. Caglayan (Bolt Beranek and Newman, Inc., Cambridge, Mass.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 529-532. 12 refs. (AIAA 79-1778)

This paper is concerned with the simultaneous utilization of boundary and interior control in large flexible spacecraft. The issue of boundary control can arise due to a given actuator placement or actuator positions can be chosen to make use of boundary control in absorbing structural vibrations. First, it is shown that boundary control can be incorporated into interior control of truncated modal control by using either integral transforms or suitable change of variables. The shortcomings of these approaches are discussed. Secondly, the recent results on nonreflective boundary control approach are summarized and interpreted. A scheme incorporating a nonreflective boundary controller along with a reduced order interior controller is proposed. (Author)

A79-45406 * # **On adaptive modal control of large flexible spacecraft.** C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 533-539. 29 refs. Grant No. NsG-1527. (AIAA 79-1779)

A recently developed strategy for adaptive sampled-data control of distributed parameter systems based on a plant modal expansion description and modal simultaneous identification and regulation algorithms is presented with frequent reference to the annular momentum control device (AMCD) test example. The requirements of observation spillover reduction and modal eigenvector shape prespecification, which are especially crucial to the proposed adaptive control strategy, are addressed. Individual low pass time filtering of sensed AMCD particle displacements is proposed for observation spillover reduction. A layered scheme incorporating 'eigenvector' shape improvement is outlined to combat the expansion basis prespecification requirement. (Author)

A79-45407 # **Stability of distributed control for large flexible structures using positivity concepts.** R. J. Benhabib, R. P. Iwens, and R. L. Jackson (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 540-548. 17 refs. (AIAA 79-1780)

A robust stability test and associated design procedure based on the positivity of operators is proposed. The test does not rely on modal truncation or high order truth models of the structure and is independent of the numerical values of the modal data. The stability criterion is applied to the plant (structure) and the controller individually, assuring global stability when the loop is closed by negative feedback. Therefore, design/stability evaluations need only iterate on the low order controller part of the loop. The method can be extended to nonlinear systems. (Author)

A79-45408 # **A learning control system extension to the modal control of large flexible rotating spacecraft.** K. R. Hall (LTV Corp., Hampton, Va.). In: Guidance and Control Conference, Boulder, Colo., August 6-8, 1979, Collection of Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 549-557. 5 refs. (AIAA 79-1781)

A proposed attitude control device for large space structures consists of a pair of oppositely spinning rings of large diameter and small cross sectional area. This report deals with the simulation of the motion of one ring and the implementation of a control system for controlling the elastodynamic motions of the ring. A novel feature of the adaptive control system is the learning feature which allows the control system to adapt to changing conditions even in the absence of identification. The out-of-plane motion is examined in detail with simulation development and control system development both in modal representation. (Author)

A79-47234 # **Relative attitude of large space structures using radar measurements.** A. R. Brook (Martin Marietta Aerospace, Denver, Colo.) and A. L. Satin (Aerospace Corp., El Segundo, Calif.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-155.* 22 p. 5 refs.

The need for accurate knowledge of relative attitude and attitude rate for station-keeping and docking of large (350 ft. diameter) space structures, is studied. It is shown that enhanced accuracy may be obtained by making use of radar measurements between the center of one structure and outlying points on the extended structure of another. In addition, the results of a covariance analysis of a sequential measurement filter are used to evaluate the adequacy of a candidate radar/transponder system for station-keeping at 1000 ft and 10 ft. It is concluded for the mission in question that two transponders capable of providing range, range-rate, azimuth and elevation data, should be located on the outlying structure of the chase vehicle near the docking interface, while a third transponder on the center column completes a minimal set suitable for long or short range tracking. M.E.P.

A79-47235 # **Large angle maneuver strategies for flexible spacecraft.** F. L. Markley (U.S. Navy, Naval Research Laboratory, Washington, D.C.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-156.* 24 p. 8 refs.

Three maneuver strategies are considered for large angle single axis slew maneuvers of a flexible spacecraft. The spacecraft is modeled by a four component state vector consisting of the center of mass angle and angular rate and the displacement and velocity of a single flexible mode. Only one controller is used, and fixed end point constraints are imposed on the maneuver. The first strategy minimizes a quadratic function of mode displacement, mode rate, and control effort. The second strategy minimizes a quadratic function of mode displacement and mode rate only, with the control effort being bounded in magnitude. Bang-bang arcs, singular arcs, and chattering arcs all appear in this case. The third strategy employs a control function that is a polynomial in time. Numerical calculations are performed for a representative case, and the performances of the three strategies are compared. (Author)

A79-47236 * # **Decoupling control of a long flexible beam in orbit.** A. S. S. R. Reddy, P. M. Bainum (Howard University, Washinton, D.C.), and H. A. Hamer (NASA, Langley Research Center, Hampton, Va.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-158.* 26 p. 15 refs. Grant No. NsG-1414.

The paper presents a method of control for large flexible systems using state variable feedback, with a long flexible beam given as an example. These feedback gains are selected: (1) based on the decoupling of the original coordinates and to obtain proper damping and (2) by applying the linear regulator problem to the individual modal coordinates separately. It is shown that the linear control law thus obtained are then evaluated by numerical integration of the non-linear system equations. Also included are results showing the effects (control spillover) on the uncontrolled modes when the number of controllers is less than the number of modes, and the effects of inaccurate knowledge of the control influence coefficients which lead to errors in the calculated feedback gains. M.E.P.

A79-49335 # **Application of Lagrange Optimization to the drag polar utilizing experimental data.** J. S. Kohn (Grumman Aerospace Corp., Bethpage, N.Y.). *American Institute of Aeronautics and Astronautics, Aircraft Systems and Technology Meeting, New York, N.Y., Aug. 20-22, 1979, Paper 79-1833.* 15 p. 14 refs.

The Lagrange Optimization, used with linear aerodynamic theory to define optimum aircraft geometry, is shown to have application to the determination of optimum control surface deflections as a function of angle of attack necessary to provide maximum trimmed L/D for a multi-plane aircraft configuration. Linear aerodynamic theory suggests a semi-empirical drag polar equation well suited to the optimization task. The equation is shown to correlate well with experimental data near aircraft cruise conditions. Such correlations are shown for selected aft and forward swept configurations up to 0.9 Mach number both in terms of total drag and drag increments due to control deflections and angle of attack. Optimum trimmed configurations are defined using experimental data and the subject optimization procedure. (Author)

A79-49832 **Dynamics and control of large space structures - An overview.** S. M. Seltzer. *Journal of the Astronautical Sciences,* vol. 27, Apr.-June 1979, p. 95-101. 11 refs.

The paper presents a survey of the efforts being undertaken to solve the problem of dynamics and control of earth-orbiting spacecraft that are large flexible structures. Among these are the Defense Advanced Research Projects Agency (DARPA) Active Control of Space Structures (ACOSS), a development program in dynamic structural control which is being developed in several phases which involve industry and Draper Laboratory. Attention is also given to the approach taken by NASA and industry. This involves the Large Space Structures Technology (LSST) Program managed by Langley Research Center. In conclusion, seven critical areas which need more work are given. These are: (1) dynamic modeling, (2) control law development, (3) digital techniques, (4) disturbance accommodation, (5) shape and or figure control, (6) effector/actuator selection, and (7) innovation. M.E.P.

A79-49833 **Flexible spacecraft control by model error sensitivity suppression.** J. R. Sesak, T. Coradetti (General Dynamics Corp., Convair Div., San Diego, Calif.), and P. Likins (Columbia University, New York, N.Y.). *Journal of the Astronautical Sciences,* vol. 27, Apr.-June 1979, p. 131-156. 25 refs.

A model error sensitivity suppression method is presented to resolve sensitivity to modelling errors and limitations of flight computers, which permit only estimators of lower order than required to estimate all dynamically significant states together. A decentralized control concept results consisting of a collection of subsystems estimators and controllers, each independently charged with a subset of the system states. The key controller concept is the penalization in the performance index of any control action that excites modeled states other than those for which the subsystem control is charged, inhibiting control spillover. It is shown that performance indices can be modified to reduce control and observation spillover arbitrarily while preserving stability, and numerical examples are developed for the simply supported beam and an idealized space platform. (Author)

A79-49834 **Direct output feedback control of large space structures.** M. J. Balas (Bolt Beranek and Newman, Inc., Cambridge, Mass.). *Journal of the Astronautical Sciences* vol. 27, Apr.-June 1979, p. 157-180. 35 refs.

Direct output feedback (DOFB) control of large structures in space (LSS) and the primary design trade-off of this method versus modern modal control (MMC) approach is presented. LSS are continuum structures requiring large dimensional models to predict their dynamic behavior, but the on-board computer capacity is limited so that active control of LSS is accomplished with a controller of smaller dimension than the dynamic structure model. This paper considers feedback control of N critical modes of a general LSS obtained by DOFB, i.e. sensor outputs are multiplied by a gain matrix to produce control actuator commands. The on-board computer capacity for DOFB is considerably lower than that for MMC, which uses a state estimator to approximate the controlled mode state from the sensor outputs and applies control gains to the estimated state, but the number of control devices for DOFB to achieve the same control performance as MMC is much higher. Both methods suffer from the effects of spillover due to the residual modes. (Author)

A79-49835 **On cost-sensitivity controller design methods for uncertain dynamic systems.** R. E. Skelton (Purdue University, West Lafayette, Ind.). *Journal of the Astronautical Sciences,* vol. 27, Apr.-June 1979, p. 181-205. 13 refs.

A 'two-model' theory of control design results when one chooses a high order 'evaluation model' to be used during simulations (evaluations) of the spacecraft system, and a low order 'controller design model' to be used during the analytical design of the control policy. Some limitations of the low order controller design model which are considered in this paper are: (1) calculations for the 'best' controller design model involve the control problem statement and the evaluation model: (2) the reduced order controller can move the poles of the evaluation model by an amount which is related to the order of the controller design model; (3) the optimum sensor and actuator locations also depend upon the order of the controller design model which is to be used; and (4) the 'best' controller design model may also be influenced by parameter sensitivity considerations. These considerations lead to a 'cost sensitivity' approach to modeling. (Author)

A79-50033 * **Indirect adaptive stabilization of a large, flexible, spinning spacering - Simulation studies.** A. L. Hamm and C. R. Johnson, Jr. (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: SOUTHEASTCON '79; Proceedings of the Region 3 Conference and Exhibit, Roanoke, Va., April 1-4, 1979. New York, Institute of Electrical and Electronics Engineers, Inc., 1979, p. 53-56. 5 refs. Grant No. NsG-1527.

A recently formulated approach to the adaptive control of distributed systems combines the simultaneous identification and control philosophy of indirect adaptive control with a modal expansion description of distributed systems. The regulation of a large, flexible, spinning spacering, one half of a dual momentum control device proposed for attitude control of large space systems, provides the example upon which the capabilities of such a synthesis method are tested via simulation. (Author)

A79-50483 # **Stabilization of the shape of a deploying surface (O stabilizatsii formy narashchivaemoi poverkhnosti).** V. I. Buiakas. *Kosmicheskie Issledovaniia,* vol. 17, July-Aug. 1979, p. 547-558. 5 refs. In Russian.

The paper considers the problem of stabilizing the shape of the radio-reflective surface of a large space telescope. It is found that the use of an automatically deploying modular structure makes it possible to control the shape of the reflective surface without elastic deformations of the telescope elements. An iterative method for determining points of reference on the stabilized surface is presented. Control laws are derived for assuring the local stability of module

points of reference for structures with sufficiently large focal distances. B.J.

A79-53063 # **Assessment of the errors of an analytical method of calculating the geocentric trajectories of a solar sail (Otsenka pogreshnostei analiticheskogo metoda rascheta geotsentricheskikh traektorii apparata s solnechnym parusom).** L. K. Grinevitskaia and E. N. Poliakhova. *Leningradskii Universitet, Vestnik, Matematika, Mekhanika, Astronomiia,* Apr. 1979, p. 95-98. In Russian.

The capability of a solar sail to compensate for disturbances acting on it during space flights is examined. The approximate least-time control of the sail angle to provide transition from the initial to the terminal state is determined on the basis of Pontriagin's principle of maximum and a proposed averaging scheme. A programmed method for calculating the minimum time required for orbital corrections is proposed. V.P.

A79-53362 **Distributed control of two typical flexible structures.** B. Govin and J. Broquet (Matra, S.A., Vélizy-Villacoublay, Yvelines, France). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-212.* 17 p.

Two studies of distributed and multiple control of flexible structures which deal with the control performance according to the sensing and actuating system location on the structure are presented. The first study examines the control of a satellite main body provided with a large flexible appendage with one degree of rotation controlled by a torque motor. Comparison is made of performance of the torque motor and of the internal main body actuator, or of both actuators according to sensing functions and locations, such as measurement of absolute motion of main body and relative motion between appendage and main body at torque motor level. The second study treats the active control of large structures built from rigid bodies connected through flexible hinges, and for one example of structure with limited number of elements the structural eigenfrequencies are determined and the modes shapes are shown. Finally, the optimum location of actuator to actively control the structure is discussed in terms of mode disturbability. A.T.

A79-53945 # **Stability of proportional-plus-derivative-plus-integral control of flexible spacecraft.** P. C. Hughes (Toronto, University, Downsview, Ontario, Canada) and T. M. Abdel-Rahman (Spar Aerospace, Ltd., Toronto, Canada). *Journal of Guidance and Control,* vol. 2, Nov.-Dec. 1979, p. 499-503. 15 refs. Natural Science and Engineering Research Council of Canada Grant No. A-4183.

The linear attitude control of flexible spacecraft is considered. The feedback law is of the proportional-plus-derivative-plus-integral class. The sensor and actuator dynamics are included, albeit in simple models. The structural flexibility model is unrestricted except for the usual assumption of small deflections. The principal result of the paper is that if the controller is unconditionally stable (with respect to gain), assuming the satellite to be rigid, then structural flexibility cannot destabilize it. This and other possibilities are illustrated by numerical examples. (Author)

N79-22177*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
POINTING AND CONTROL SYSTEM ENABLING TECHNOLOGY FOR FUTURE AUTOMATED SPACE MISSIONS
J. B. Dahlgren 30 Dec. 1978 77 p refs
(Contract NAS7-100)
(NASA-CR-158513; JPL-PUB-79-23) Avail: NTIS HC A05/MF A01 CSCL 22B

Future automated space missions present challenging opportunities in the pointing-and-control technology disciplines. The enabling pointing-and-control system technologies for missions from 1985 to the year 2000 were identified and assessed. A generic mission set including Earth orbiter, planetary, and other missions which predominantly drive the pointing-and-control requirements was selected for detailed evaluation. Technology candidates identified were prioritized as planning options for future NASA-OAST advanced development programs. The primary technology thrusts in each candidate program were cited, and advanced development programs in pointing-and-control were recommended for the FY 80 to FY 87 period, based on these technology thrusts. J.M.S.

N79-25122*# Howard Univ., Washington, D. C. School of Engineering.
THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES, 2. PART A: SHAPE AND ORIENTATION CONTROL USING POINT ACTUATORS Final Report
Peter M. Bainum and A. S. S. R. Reddy Jun. 1979 78 p refs
(Grant NsG-1414)
(NASA-CR-158684) Avail: NTIS HC A05/MF A01 CSCL 22B

The equations of planar motion for a flexible beam in orbit which includes the effects of gravity gradient torques and control torques from point actuators located along the beam was developed. Two classes of theorems are applied to the linearized form of these equations to establish necessary conditions for controlability for preselected actuator configurations. The feedback gains are selected: (1) based on the decoupling of the original coordinates and to obtain proper damping, and (2) by applying the linear regulator problem to the individual model coordinates separately. The linear control laws obtained using both techniques were evaluated by numerical integration of the nonlinear system equations. Numerical examples considering pitch and various number of modes with different combination of actuator numbers and locations are presented. The independent model control concept used earlier with a discretized model of the thin beam in orbit was reviewed for the case where the number of actuators is less than the number of modes. Results indicate that although the system is controllable it is not stable about the nominal (local vertical) orientation when the control is based on modal decoupling. An alternate control law not based on modal decoupling ensures stability of all the modes. S.E.S.

N79-27655*# Astro Research Corp., Carpinteria, Calif.
STUDY OF MEMBRANE REFLECTOR TECHNOLOGY Final Report
Karl Knapp and John Hedgepeth 2 Jan. 1979 39 p Sponsored by NASA Prepared for JPL
(Contract JPL-955081)
(NASA-CR-158729; ARC-TN-1071; JPL-9950-104) Avail: NTIS HC A03/MF A01 CSCL 10A

Very large reflective surfaces are required by future spacecraft for such purposes as solar energy collection, antenna surfaces, thermal control, attitude and orbit control with solar pressure, and solar sailing. The performance benefits in large membrane reflector systems, which may be derived from an advancement of this film and related structures technology, are identified and qualified. The results of the study are reported and summarized. Detailed technical discussions of various aspects of the study are included in several separate technical notes which are referenced. G.Y.

N79-29215*# Bendix Corp., Teterboro, N. J. Guidance Systems Div.
SPACE CONSTRUCTION BASE CONTROL SYSTEM Final Report
27 Oct. 1978 362 p refs
(Contract NAS8-32660)
(NASA-CR-161288) Avail: NTIS HC A16/MF A01

Aspects of an attitude control system were studied and developed for a large space base that is structurally flexible and

whose mass properties change rather dramatically during its orbital lifetime. Topics of discussion include the following: (1) space base orbital pointing and maneuvering; (2) angular momentum sizing of actuators; (3) momentum desaturation selection and sizing; (4) multilevel control technique applied to configuration one; (5) one-dimensional model simulation; (6) N-body discrete coordinate simulation; (7) structural analysis math model formulation; and (8) discussion of control problems and control methods. Author

N79-29222 Howard Univ., Washington, D. C.
THE DYNAMICS AND OPTIMAL CONTROL OF SPINNING SPACECRAFT WITH MOVABLE TELESCOPING APPENDAGES Ph.D. Thesis
Ramasamy Gounder Sellappan 1977 178 p
Avail: Univ. Microfilms Order No. 7915942

Two types of telescoping appendages were considered: (1) where the end masses are mounted at the end of the assumed massless booms; and (2) where the appendages are assumed to consist of a uniformly distributed homogeneous mass throughout their lengths. For the telescoping system, Eulerian equations of motion were developed. Closed-form analytical solutions for the time response of the transverse components of angular velocity were obtained for the spacecraft hub with spherical and nearly spherical mass distribution. As an application to spacecraft rescue and recovery, booms were extended along all the principal axes to (1) detumble a symmetrical spacecraft, and (2) achieve a desired final spin about one of the principal axes. Dissert. Abstr.

05
ELECTRONICS

Includes techniques for power and data distribution.

N79-24441*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
A PROGRAMMABLE POWER PROCESSOR FOR A 25-kW POWER MODULE
Roy Lanier, Jr., Robert E. Kapustka, and John R. Bush, Jr. Jan. 1979 23 p refs
(NASA-TM-78215) Avail: NTIS HC A03/MF A01 CSCL 10B

A discussion of the power processor for an electrical power system for a 25-kW Power Module that could support the Space Shuttle program during the 1980's and 1990's and which could be a stepping stone to future large space power systems is presented. Trades that led to the selection of a microprocessor-controlled power processor are briefly discussed. Emphasis is given to the power processing equipment that uses a microprocessor to provide versatility that allows multiple use and to provide for future growth by reprogramming output voltage to a higher level (to 120 V from 30 V). Efficiency data from a breadboard programmable power processor are presented, and component selection and design considerations are also discussed. G.Y.

06
ADVANCED MATERIALS

Includes matrix composites, polyimide films and thermal control coatings, and space environmental effects on these materials.

A79-34754 # **A nonlinear stress-strain law for metallic meshes.** S. Tang, R. Boyle, J. Whiteside, and R. Anderson (Grumman Aerospace Corp., Bethpage, N.Y.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 459-466. 11 refs. (AIAA 79-0936)

Due to their high strength and light weight properties, use of flexible knitted mesh materials in current and future space-based antennas is increasing. In the present paper, a two-dimensional orthotropic nonlinear elastic stress-strain law is proposed for gold-coated tricot metallic mesh material of diamond-knit pattern. This constitutive relation accommodates geometrically nonlinear behavior due to the large displacement of the diamond-shape cell as well as the nonlinear behavior due to the knitted configuration of the cell. Comparison with experimental data shows the proposed constitutive law provides a reasonably good description of the stress-strain behavior of this material. B.J.

A79-36190 # **Effects of electron irradiation on large insulating surfaces used for European Communications Satellites.** J. Reddy and B. E. Serene (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands). *(NASA and U.S. Air Force, Spacecraft Charging Technology Conference, Colorado Springs, Colo., Oct. 31-Nov. 2, 1978.) ESA Journal,* vol. 3, no. 1, 1979, p. 41-47. 5 refs.

External configuration of the ESA's Orbital Test Satellite (OTS) and its derivatives ECS (European Communications Satellite) and Marecs (Maritime ECS) is such that the VHF shield assembly and the antenna dish are in contact with the space plasma and become charged electrostatically. Results of tests performed in a vacuum chamber show that although the charge reaches a reasonably high potential, the effects of discharges on material properties and electromagnetic interference are relatively insignificant for the antenna structure while for the VHF shield assembly the opposite is true. Considerable damage to the vacuum-deposited aluminum is observed. Associated with this are large transient currents that could severely affect the system electronics. With current external satellite design largely dictated by thermal (as well as handling and economic) requirements, a proper solution to this problem appears to be to provide the best possible desensitization of all susceptible circuitry. V.T.

A79-43228 **The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Books 1 & 2.** Symposium sponsored by the Society for the Advancement of Material and Process Engineering. Azusa, Calif., Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering Series. Volume 24, Book 1 and Book 2), 1979. Book 1, 858 p.; Book 2, 778 p. Price of two books, $56.

The proceedings focus on developments in materials technology for energy and environmental problems of the 1980s. Particular consideration is given to nonterrestrial material processing and manufacturing of large space systems, sandwich constructions for aircraft and communications, materials for airline safety, thermal coatings for missile warhead fire protection, and satellite applications of metal matrix composites. Papers are also presented on polyimide/graphite, aluminum/SiC, and fiber reinforced titanium composites, pressure vessel steels for coal gasifiers, environmental effects of composite material processing, adhesive bonding of sandwich structures, heatshield materials for rocket launching systems, and the effects of particulates on solar cells. A.T.

A79-43231 * **Graphite fiber reinforced glass matrix composites for aerospace applications.** K. M. Prewo, J. F. Bacon (United Technologies Research Center, East Hartford, Conn.), and D. L. Dicus (NASA, Langley Research Center, Materials Research Branch, Hampton, Va.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 1. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 61-71. 7 refs. Contract No. NAS1-14346.

The graphite fiber reinforced glass matrix composite system is described. Although this composite is not yet a mature material, it possesses low density, attractive mechanical properties at elevated temperatures, and good environmental stability. Properties are reported for a borosilicate glass matrix unidirectionally reinforced with 60 volume percent HMS graphite fiber. The flexural strength and fatigue characteristics at room and elevated temperature, resistance to thermal cycling and continuous high temperature oxidation, and thermal expansion characteristics of the composite are reported. The properties of this new composite are compared to those of advanced resin and metal matrix composites showing that graphite fiber reinforced glass matrix composites are attractive for aerospace applications. (Author)

A79-43302 **Moisture effects on spacecraft structures.** J. Hertz (General Dynamics Corp., Convair Div., San Diego, Calif.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 965-978.

The various effects of moisture on graphite/epoxy composites are described with particular emphasis on the resultant changes in physical dimensions. Details are presented on material selection for space applications including material design allowables, outgassing, microcracking, and moisture effects. Absorption of moisture is described as a function of laminate thickness, ply orientation, relative humidity, and temperature. The weight gain as a function of time is correlated to change in length. Details are presented on desorption both at ambient pressure and in vacuum as a function of time and temperature. The use of metallic coatings for the sealing of composites against moisture absorption is described, and the effects of these coatings on overall composite coefficient of thermal expansion and weight are evaluated. (Author)

A79-43305 * **Space radiation effects on composite matrix materials - Analytical approaches.** C. Giori (IIT Research Institute, Chicago, Ill.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1012-1020. Contract No. NAS1-15469.

In-vacuo ultraviolet and gamma radiation exposure tests are utilized in a study aimed at the identification of radiation damage mechanisms in composite materials, with the objective of predicting the long-term behavior of composite structures in a space environment at geosynchronous orbit. Physical and chemical methods of polymer characterization are utilized for the study of composite matrix degradation, in conjunction with GC/MS techniques for the analysis of volatile by-products. (Author)

A79-43306 **Space radiation effects on spacecraft materials.** G. L. Brown, J. F. Thomasson, and R. M. Kurland (TRW Defense and Space Systems Group, Redondo Beach, Calif.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1021-1031. Contract No. F04701-74-C-0562.

An experimental investigation is being conducted to determine changes in thermophysical and tensile properties of polymeric film materials and mechanical properties of certain composite systems when exposed to simulated combined elements of a synchronous equatorial orbit space environment. The materials examined are presently being used or have proposed application as external materials on long lifetime space systems. The facility used for testing permits sizeable quantities of test specimens to be exposed in vacuum to a combined simulation of the critical elements of the natural space environment and provides for in situ evaluation of the radiation effects. This paper briefly describes the testing facility and test procedures and presents key thermophysical and tensile test results. It is shown that some materials experience substantial changes in their properties due to radiation exposure. (Author)

A79-43307 **Materials evaluation for use in long-duration space missions.** R. L. Long (Rockwell International Corp., Satellite Systems Div., Downey, Calif.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1032-1038. 7 refs.

Methods are outlined that have the potential of predicting the performance of untried, newly developed materials so these may be used to construct vehicles suitable for long-duration missions in known but variable space environments. One of the methods uses the concept of accelerated aging by intensifying space environment components and the limitations of this method are described. A second more innovative method is based on the concept like materials perform in a similar manner and uses the real-time performance of proven materials to predict the performance of a new material containing like functional groups. (Author)

A79-43321 **Satellite applications of metal-matrix composites.** H. H. Armstrong (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1250-1264. 7 refs. Research supported by the Lockheed Independent Research and Development Program; Contract No. F33615-77-C-5190. ARPA Order 3411.

Studies concerning the application of metal-matrix composites in satellites, for which high stiffness, low expansion, high conductivity, and the absence of moisture absorption and outgassing may be requirements, show material systems composed of continuum-filament fibers in a metal matrix are particularly attractive. Graphite, boron, silicon/carbide, and aluminum/oxide fibers in a matrix of aluminum of magnesium are compared to graphite/epoxy and conventional materials. The system effectiveness of graphite fibers in aluminum and magnesium is shown to be very good in satellite design applications in which thermal/structural distortion or high specific stiffness is a major consideration. Characterization of high modulus graphite fibers in aluminum metal-matrix materials to establish a reliable data base and use of these data in the design of space structures are discussed. (Author)

A79-43322 **The application of metal-matrix composites to spaceborne parabolic antennas.** W. D. Wade and A. M. Ellison (Lockheed Missiles and Space Co., Inc., Space Systems Div., Sunnyvale, Calif.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1265-1275.

The application of graphite-reinforced metal composites is investigated for large deployable antennas. The performance of large parabolic reflectors is discussed, and the requirements for stiffness and precise surface accuracy are established. The wraprib style deployable antenna is described and special problems associated with the design are discussed. The design requirements considered include low thermal and structural distortion, dynamic response, rib stiffness and stability, and long-term storage. These design requirements result in the need for materials having high specific stiffness, low thermal expansion, high thermal conductivity, good micro-yield strength, low outgassing, and resistance to dimensional change resulting from moisture absorption. A point design of the wrap-rib antenna is used to compare performance with existing and projected materials. Materials considered include graphite-epoxy, graphite-aluminum, and graphite-magnesium. (Author)

A79-43323 **Thermally stable, thin, flexible graphite-fiber/aluminum sheet.** R. F. Karlak (Lockheed Research Laboratories, Palo Alto, Calif.) and E. Willner (Lockheed Missiles and Space Co., Inc., Satellite System Div., Sunnyvale, Calif.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1276-1287. Research supported by the Lockheed Independent Research and Development Program; Contract No. F33615-77-C-5190.

Effective utilization of graphite-fiber/aluminum sheet's exceptional longitudinal properties, for furlable space antenna ribs, requires the simultaneous optimization of in-plane thermal properties and bending characteristics. This has been accomplished by a combination of alloy selection, fabrication parameters, and heat treatments. The flexural characteristics of the material are discussed in light of lamination theory and the mechanical properties of the core material and aluminum face sheets after aging and subsequent thermal processing to mitigate the detrimental influence of internal residual stresses that develop on cooling from the artificial aging temperature. (Author)

A79-43330 **Dimensional stability investigation - Graphite/epoxy truss structure.** R. L. Kirlin (Martin Marietta Aerospace, Denver, Colo.) and G. E. Pynchon (Composite Optics, Inc., San Diego, Calif.). In: The enigma of the eighties: Environment, economics, energy; Proceedings of the Twenty-fourth National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979. Book 2. Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1979, p. 1356-1371.

The stability characteristics of a graphite/epoxy truss structure made of unidirectional tape and woven fabric are reported. Tube and

joint specimens were subjected to an evaluation of dimensional stability by thermal cycling to determine coefficients of thermal expansion (CTE), and to moisture exposure to measure dimensional strains due to changed moisture content. The CTE data indicate that the onset of microcracking is below -100 F for this composite system, and that between -100 F and +200 F the components are stable in terms of thermal expansion behavior. The humidity desorption data shows that drying from an equilibrium moisture content corresponding to 50% relative humidity will cause a longitudinal strain of 40 ppm in the tubes and 70 ppm in the joints. These values are dimensionally equivalent to the results of a temperature change of up to 200 F in the axial direction of the tubes and 90 F in the axial direction of the joints. A.T.

A79-46700 # **Materials degradation in space environments.** M. R. Louthan, Jr., R. P. McNitt, and R. D. Sisson (Virginia Polytechnic Institute and State University, Blacksburg, Va.). *American Institute of Aeronautics and Astronautics, Fluid and Plasma Dynamics Conference, 12th, Williamsburg, Va., July 23-25, 1979, Paper 79-1508*. 6 p. 28 refs.

Three characteristics of space environments - high radiation levels, vacuum, and extreme temperatures - must be considered in relation to in-flight materials degradation. Design criteria which provide totally satisfactory ground-based performance may be inadequate for space. In the present paper selected degradation problems are discussed with emphasis on the adverse effects of radiation on semiconductor devices, the effects of extreme temperatures on the impact properties of metallic and nonmetallic structural members and the effects of vacuum on the fatigue and wear of working components. B.J.

N79-24036*# European Space Agency, Paris (France)
EFFECTS OF ELECTRON IRRADIATION ON LARGE INSULATING SURFACES USED FOR EUROPEAN COMMUNICATIONS SATELLITES
J. Reddy and B. E. H. Serene *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 570-586 refs

Avail: NTIS HC A99/MF A01 CSCL 22B

Samples of aluminized Kapton used for passive thermal control on the VHF shield and the antenna dish of ESA's OTS satellite and its derivatives were subjected to an incident electron beam of 25 keV and irradiated for 8 hours at room temperature and at -173 C under a vacuum of the 10 to the minus 6 th power torr. Visual observations during electron irradiation, measurements of leakage current and discharge characteristics, and material degradation following completion of irradiation are discussed. A.R.H.

N79-30297*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
GRAPHITE/POLYIMIDE COMPOSITES
H. Benson Dexter, ed. and John G. Davis, Jr., ed. Aug. 1979 449 p refs Proc. held at Hampton, Va., 28 Feb. - 1 Mar. 1979
(NASA-CP-2079; L-12953) Avail: NTIS HC A19/MF A01 CSCL 11D

Technology developed under the Composites for Advanced Space Transportation System Project is reported. Specific topics covered include fabrication, adhesives, test methods, structural integrity, design and analysis, advanced technology developments, high temperature polymer research, and the state of the art of graphite/polyimide composites.

N79-30304*# Rockwell International Corp., Downey, Calif.
FABRICATION OF STRUCTURAL ELEMENTS
Fred J. Darms, Jr. *In* NASA. Langley Res. Center Graphite/Polyimide Composites Aug. 1979 p 111-122

(Contract NAS1-15183)
Avail: NTIS HC A19/MF A01 CSCL 11D

The laminate fabrication procedures and quality assurance ultrasonic C-scan results used for structural elements are described. These procedures are the result of processing eleven lots of graphite/PMR-15 prepreg tape materials and two lots of graphite/NR-150B2. Early processing difficulties with NR-150B2 composites were corrected, permitting the fabrication of quality specimens from either of the two currently prescribed matrix materials. The quality of all deliverable specimens is measured by the control of fiber content, glass transition temperature, and void content, as well as laminate ultrasonic C-scan data. J.M.S.

N79-30328*# McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.
GRAPHITE/POLYIMIDES STATE-OF-THE-ART PANEL DISCUSSION
Robert C. Curley *In* NASA. Langley Res. Center Graphite/Polyimide Composites Aug. 1979 p 445-450

Avail: NTIS HC A19/MF A01 CSCL 11D

A brief overview of current and planned applications of graphite/polyimide composites is presented. A short discussion of technical problems delaying the application of graphite polyimide composites in aerospace structures and near-term solutions to these problems are also included. Author

N79-30737# AEG-Telefunken, Wedel (West Germany).
NEW FLEXIBLE SUBSTRATES WITH ANTI-CHARGING LAYERS FOR ADVANCED LIGHTWEIGHT SOLAR ARRAYS
D. Ruesch *In* ESA Photovoltaic Generators in Space Nov. 1978 p 41-48 refs Sponsored by Bundesmin. fuer Forsch. u. Technol.
Avail: NTIS HC A15/MF A01

Increasing power demands for future space missions has stimulated the development of large-area flexible solar arrays. Several flexible substrates for application to large area flexible solar arrays according to mission requirements were developed. Various methods for providing a rear-side anti-charging layer were also developed. The mechanical and physical properties of glass fiber, carbon fiber, and aramid fiber, reinforced Kapton substrates are presented. Fabrication processes are described. Recommendations are given for suitable applications of the various substrate types in space solar arrays. Author (ESA)

07
ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.

A79-34731 # **Space manipulators - Present capability and future potential.** J. D. Graham, R. Ravindran (Spar Aerospace, Ltd., Toronto, Canada), and K. Knapp (Astro Research Corp., Carpinteria, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 243-253. (AIAA 79-0903)

The various tasks manipulators will perform in space to the year 2000 are discussed. Emphasis in the paper is placed on the development of the Shuttle Remote Manipulator System (SRMS), with a description presented of the overall system and the component subsystems. Potential modifications to the SRMS are discussed together with the expected increased capability and performance. Future requirements for other types of manipulators are also discussed together with likely required design features. B.J.

A79-34757 # **Large space system automated assembly technique.** P. Slysh (General Dynamics Corp., Convair Div., San Diego, Calif.) and D. A. Kugath (General Electric Co., Space Div., Philadelphia, Pa.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 481-492. (AIAA 79-0939)

A concept (LSAT) has been developed for compatibly designing a truss frame space structure and an assembler that assembles and maintains the structure plus its subsystems, lines, and working surfaces. Use is made in this concept of programmed assembly, maintenance, and repair processes based on similar state-of-the-art industrial automated processes. The structure is progressively constructed by the assembler which is carried through the structure at a constant velocity by means of belt transports that engage the structure at its nodes. An assembler consists of two-crawlers joined by an articulated coupling. The forward crawler carries stacks of struts and nodes and assembler arms that assemble the structure. The rear crawler houses most of the control, spares, power, and communication subsystems, and is essential for the truss junction construction process. (Author)

A79-34982 * # **Advanced teleoperators.** A. K. Bejczy (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Astronautics and Aeronautics,* vol. 17, May 1979, p. 20-31. 33 refs. Contract No. NAS7-100.

Advanced teleoperators are discussed, with emphasis on the remote manipulation system designed to perform such actions as grasping, orienting, moving, placing, and inserting objects. Geometrical performance dimensions are considered, indicating that a manipulator is limited to three-orders-of-magnitude ratio of workspace extension to positioning accuracy. The control system is examined, showing that a manipulative task requires coordination of several joints, with the relationship between the task definers and the joint variables given by complex trigonometrical transformations. Control modes developed in the last 30 years are noted, including program controlled industrial 'robots' which can endlessly repeat a fixed sequence of motions without operator intervention, and the sensor-referenced/computer-controlled mode manipulators. Advanced proximity sensor systems are taken into account, with emphasis on the applications of the force-torque and slip models. The proximity sensor system for the shuttle-size manipulator is described. A.A.

A79-34985 * # **Construction in space - Toward a fresh definition of the man/machine relation.** H. H. Watters and J. W. Stokes (NASA, Marshall Space Flight Center, Huntsville, Ala.). *Astronautics and Aeronautics,* vol. 17, May 1979, p. 42-45, 63.

The EVA (extravehicular activity) project forming part of the space construction process is reviewed. The manual EVA construction, demonstrated by the crew of Skylab 3 by assembling a modest space structure in the form of the twin-pole sunshade, is considered, indicating that the experiment dispelled many doubts about man's ability to execute routine and contingency EVA operations. Tests demonstrating the feasibility of remote teleoperator rendezvous, station keeping, and docking operations, using hand controllers for direct input and television for feedback, are noted. Future plans for designing space construction machines are mentioned. A.A.

A79-40539 **Teleoperator system for management of satellite deployment and retrieval.** J. R. Tewell and R. A. Spencer (Martin Marietta Aerospace, Denver, Colo.). In: NTC '78; National Telecommunications Conference, Birmingham, Ala., December 3-6, 1978, Conference Record. Volume 1. Piscataway, N.J., Institute of .Electrical and Electronics Engineers, Inc., 1978, p. 16.5.1-16.5.4.

A Teleoperator Retrieval System (TRS) is now being developed. This system, a remotely controlled maneuverable spacecraft, is briefly described. While the TRS will initially be used in the Skylab boost mission, the emphasis of this paper is on the future applications envisioned for the vehicle and its derivatives. The operational availability of the TRS to perform satellite deployment, satellite retrieval, and on-orbit servicing allows spacecraft designers and mission planners significant flexibility and new approaches to low-cost design. (Author)

A79-47201 # **On-orbit assembly of Large Space Structures /LSS/ using an autonomous rendezvous and docking.** F. A. Vandenberg (Martin Marietta Aerospace, Denver, Colo.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-100.* 18 p.

The paper describes how Large Space Structures (LSS) components will accomplish autonomous rendezvous and docking, a capability which will be needed more frequently in the Space Shuttle era. It is shown that a nearly optimum rendezvous (in respect to propellant consumption) between the vehicles in nearly circular and coplanar orbits can be accomplished by using parabolic control curves in it proportional navigation algorithm. Finally, a method of accomplishing an optimum autonomous rendezvous is presented, that does not need complex orbital equations of the vehicles' states to execute a Hohmann transfer type of rendezvous. M.E.P.

A79-53421 * **Manned remote work station - Safety and rescue considerations.** C. A. Nathan (Grumman Aerospace Corp., Bethpage, N.Y.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-A-19.* 20 p. 10 refs. Contract No. NASg-15581.

It is noted that due to restrictions of payload and volume limitations of current and projected launch systems, space construction of ultralarge space structures is essential. The present paper discusses the concepts of a key piece of construction equipment needed to support assembly of such large structures. Attention is given to the manned remote work station (MRWS), a universal crew cabin to be used as a construction cherry picker, space crane turret, work station on a construction base rail system, or a free flyer. Concepts and safety and rescue requirements for this spacecraft are delineated for early applications in support of Shuttle operations, as well as applications in support of a mid to late 1980's space construction base. Finally, applications in support of constructing and maintaining a solar power satellite system are covered. M.E.P.

07 ASSEMBLY CONCEPTS

N79-22562*# Lockheed Missiles and Space Co., Sunnyvale, Calif.

AUTOMATIC IN-ORBIT ASSEMBLY OF LARGE SPACE STRUCTURES

Georges G. Jacquemin *In* NASA. Johnson Space Center The 13th Aerospace Mech. Symp. 1979 p 283-291 refs

Avail: NTIS HC A13/MF A01 CSCL 22A

The automated assembly of a large number of components required for the on-orbit erection of large tetrahedral space platforms is described. The assembly machine is a huge jig in which a multitude of mechanisms must operated continuously in the thermo vacuum environment of space and under the control of computers programmed to command every step of each motion. The concepts are presented to determine the most reliable solution. Continuous operation of mechanisms in space presents many unresolved problems, with regard to lubrication of unprotected devices, such as chain drives, which must maintain reasonable positioning tolerances. S.E.S.

N79-28201*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.

AUTONOMOUS MECHANICAL ASSEMBLY ON THE SPACE SHUTTLE: AN OVERVIEW

M. H. Raibert 15 Jul. 1979 34 p refs

(Contract NAS7-100)

(NASA-CR-158818; JPL-PUB-79-62) Avail: NTIS HC A03/MF A01 CSCL 22A

The space shuttle will be equipped with a pair of 50 ft. manipulators used to handle payloads and to perform mechanical assembly operations. Although current plans call for these manipulators to be operated by a human teleoperator. The possibility of using results from robotics and machine intelligence to automate this shuttle assembly system was investigated. The major components of an autonomous mechanical assembly system are examined, along with the technology base upon which they depend. The state of the art in advanced automation is also assessed. A.R.H.

08
PROPULSION

Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.

A79-34704 * # **Space propulsion technology overview.** J. J. Pelouch, Jr. (NASA, Lewis Research Center, Propulsion Systems Section, Cleveland, Ohio). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 24-29. (AIAA 79-0860)

This paper discusses Shuttle-era, chemical and electric propulsion technologies for operations beyond the Shuttle's orbit with focus on future mission needs and economic effectiveness. The adequacy of the existing propulsion state-of-the-art, barriers to its utilization, benefit of technology advances, and the prognosis for advancement are the themes of the discussion. Low-thrust propulsion for large space systems is cited as a new technology with particularly high benefit. It is concluded that the Shuttle's presence for at least two decades is a legitimate basis for new propulsion technology, but that this technology must be predicated on an awareness of mission requirements, economic factors, influences of other technologies, and real constraints on its utilization. (Author)

A79-34716 # **Orbit transfer vehicle propulsion for transfer of Shuttle-deployed large spacecraft to geosynchronous orbit.** W. J. Ketchum (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 123-127. 5 refs. (AIAA 79-0880)

An optimization methodology has been developed for Shuttle upper-stage propulsion systems that will transfer a new generation of large spacecraft structures to geosynchronous orbit. The payload and Orbit Transfer Vehicle (OTV) comprise a single Shuttle flight for maximum utilization of the Shuttle, emphasizing a short-length, high-performance OTV. This analysis evaluates the size and weight of the expanded structure and the performance of the OTV as a function of thrust-to-weight ratio and includes optimization of low-thrust trajectories to maximize structure size and determine optimum engine thrust level. Results presented indicate significant improvement using a low-thrust capability (less than 3 k) liquid O2-H2 engine, and compare fixed thrust and throttled engines as well as solid motors (IUS) and a solar electric propulsion stage (SEPS). (Author)

A79-34718 * # **Inductive energy storage for MPD thrusters.** L. K. Rudolph and R. M. Jones (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 136-145. 14 refs. Contract No. NAS7-100. (AIAA 79-0883)

The high thrust density of the self-field magnetoplasmadynamic (MPD) thruster makes it a promising candidate for many advanced space missions. The high power requirements of this thruster lead to its operation in a pulsed mode from an energy storage device. The system characteristics of an inductive energy storage circuit with a solar array power from 25 kwe to 400 kwe are considered, by solving the circuit equations for the inductor charge and discharge phases. Using simple analytic models of the circuit components, the total system efficiency and inductance are determined as functions of the array output power and circuit resistance. The total system efficiency increases with array power and is acceptable only for low values of circuit resistance, indicating that superconducting circuitry may be desirable. The optimum charge-discharge cycle changes fundamentally as the circuit resistance is decreased through a critical value dependent on the thruster operating characteristics. (Author)

A79-34735 * # **Planetary mission requirements, technology and design considerations for a solar electric propulsion stage.** M. J. Cork, R. C. Hastrup, W. A. Menard, and R. N. Olson (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 279-289. 8 refs. Contract No. NAS7-100. (AIAA 79-0908)

High energy planetary missions such as comet rendezvous, Saturn orbiter and asteroid rendezvous require development of a Solar Electric Propulsion Stage (SEPS) for augmentation of the Shuttle-IUS. Performance and functional requirements placed on the SEPS are presented. These requirements will be used in evolution of the SEPS design, which must be highly interactive with both the spacecraft and the mission design. Previous design studies have identified critical SEPS technology areas and some specific design solutions which are also presented in the paper. (Author)

A79-34738 * # **Solar thermoelectric power generation for Mercury orbiter missions.** M. Swerdling (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.) and V. Raag (Syncal Corp., Sunnyvale, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 306-314. 8 refs. Contract No. NAS7-100. (AIAA 79-0915)

Mercury orbiter mission study results have shown that conventional silicon solar cell array technology is not adequate to produce power because of expected temperatures which range from -90 C to +285 C in about 50 minutes for 16 sun eclipses/day. The solar thermoelectric generator (STG), which requires relatively high temperatures, is being developed as a replacement power source. Several thermoelectric technologies (i.e., lead telluride alloys, bismuth telluride, selenide, and silicon-germanium alloys have been examined for their suitability. Solar concentrator configurations (i.e., flat plate, Fresnel lens, mini-cone, and Cassegrain types) were also studied as candidates for increasing incident radiation during Mercury orbital operations. Detailed results are presented, and show that an STG design based on the use of silicon-germanium alloy thermoelectric material and using high-voltage thermopiles with individual miniconical concentrators presents the optimum combination of technology and configuration for minimizing power source mass. (Author)

A79-34772 # **Is a versatile orbit transfer stage feasible.** D. A. Heald (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 594-599. 11 refs. (AIAA 79-0866)

Orbital Transfer Vehicle (OTV) concepts include modular, all-propulsive, and aeromaneuvering configurations. Engine candidates include expander or staged combustion cycles which are throttleable from 20K pounds thrust and multiple installations of

new technology engines in the 3K range. The best direction of OTV development may be an evolutionary program starting with Centaur, growing to larger reusable systems, and ultimately using aerodynamic braking to return to the Orbiter or to earth. B.J.

A79-34774 * # **Increased capabilities of the 30-cm diameter Hg ion thruster.** V. K. Rawlin and C. E. Hawkins (NASA, Lewis Research Center, Cleveland, Ohio). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979. 20 p. 21 refs. (AIAA 79-0910)

A 30-cm-diam mercury ion thruster, using two or three grid ion accelerating systems, is operated at increased values of beam current. Comparisons with the SEP (Solar Electric Propulsion) and EPSEP (Extended Performance SEP) baseline thrusters are made with respect to performance and lifetime. It is found that when a third, or decelerator, grid is added to the conventional two-grid optics of a SEP-like thruster, the ion beam focusing properties are improved, as expected from theoretical considerations. The total thruster efficiency as a function of specific impulse, is increased for values of specific impulse in the range 1200-2800 sec. Lifetime test results predict a thruster lifetime, under space conditions, not less than that of the baseline SEP thruster. S.D.

A79-34847 # **High performance solar sails and related reflecting devices.** K. E. Drexler. *Princeton University and American Institute of Aeronautics and Astronautics, Conference on Space Manufacturing Facilities, 4th, Princeton University, Princeton, N.J., May 14-17, 1979, AIAA Paper 79-1418.* 8 p. 6 refs. NSF-supported research.

High performance solar sails are light tension structures bearing space-manufactured, thin-film reflecting elements. They offer thrust-to-mass ratios 20 to 80 times those of proposed deployable sails. Development costs and risks appear modest. The low cost expected for sail production promises to make these sails more cost-effective than solar electric propulsion for most missions of interest. Applications to near-earth orbital transfers, deep space scientific missions (some unique), and nonterrestrial resource recovery are examined and found attractive. In the latter application, sails permit recovery of asteroidal resources with a very low initial investment. The promise of high performance, low cost, and great versatility recommend this system for further study. (Author)

A79-39815 * # **Low-thrust chemical orbit transfer propulsion.** J. J. Pelouch, Jr. (NASA, Lewis Research Center, Space Propulsion and Power Div., Cleveland, Ohio). *AIAA, SAE, and ASME, Joint Propulsion Conference, 15th, Las Vegas, Nev., June 18-20, 1979, AIAA Paper 79-1182.* 20 p.

The need for large structures in high orbit is discussed in terms of the many mission opportunities which require such structures. Mission and transportation options for large structures are presented, and it is shown that low-thrust propulsion is an enabling requirement for some missions and greatly enhancing to many others. A general comparison of electric and low-thrust chemical propulsion is made and the need for and requirements of low-thrust chemical propulsion are discussed in terms of the interactions that are perceived to exist between the propulsion system and the large structure. (Author)

A79-47204 # **The inclination change for solar sails and low earth orbit.** T. O. Morgan (United Technologies Corp., Chemical Systems Div., Sunnyvale, Calif.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Provincetown, Mass., June 25-27, 1979, AAS Paper 79-104.* 17 p.

A solar sail has been developed as a Space Shuttle Small Self-Contained Payload Unit in order to demonstrate the thrust obtainable from solar radiation pressure. In this paper, the change in orbital inclination expected to result from the thrust of the solar sail in a minimum drag configuration in low earth orbit is calculated. A two-variable asymptotic expansion method is employed to solve the orbital equations of motion of a 10,000-sq ft solar sail for modes of sail orientation including variable and fixed roll angles around the instantaneous velocity vector. Results show that for a typical launch date an inclination change of 1.5 deg over the 60-day orbital lifetime of the mission can be achieved, with a change of 2.5 deg expected for a launch when the sun-earth system is in the optimal configuration. Little performance gain is noted for an active roll control mode over a fixed optimal mean roll angle. A.L.W.

A79-51904 * **SEP solar array development testing.** R. V. Elms, Jr. (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.) and L. E. Young (NASA, Marshall Space Flight Center, Huntsville, Ala.). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings. Volume 2. Washington, D.C., American Chemical Society, 1979, p. 1273-1277. Contract No. NAS8-31352.

This paper describes the test program of a lightweight 25 kW solar array for solar electric propulsion. A full-scale development wing was made of aluminum with the containment box cover of graphite-epoxy, while the flight design array wing uses a graphite-epoxy structure. The full-scale continuous longeron array extension mast was tested for performance on a water table, and the full scale wing was functionally tested to demonstrate automatic containment box unlocking, wing extension, and retraction, blanket tensioning, and automatic application of blanket preload. The wing was then tested to the Shuttle acoustic environment, followed by a thermal/vacuum test in which the wing was extended and retracted at high and low temperature. Finally, the wing was tested in vibration with sine and random vibration environments. A.T.

A79-53258 **Payload capacity of Ariane launched geostationary satellites using an electric propulsion system for orbit raising.** G. Krülle (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Stuttgart, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-32.* 22 p. 37 refs.

The status of electric propulsion (EP) development, orbit raising strategies, assessed payload requirements, and comparisons of geostationary spacecraft with a solar electric propulsion system (SEPS) used with the West German radio frequency ion thruster RIT-35 electric propulsion system is presented. The RIT-10 system being qualified as an electric north-south keeping system in TV-Sat and the larger RIT-35 primary propulsion system being developed are described, noting that advantages of using electric primary propulsion (EPS) are transfer missions, station keeping, and attitude and shape control of large satellites. The principal orbit raising strategies using EP, solar cell degradation, electrically raised Ariane spacecraft concepts, and the electrically propelled TV satellite configuration, propulsion system, solar generator, and mission characteristics are discussed. It was concluded that the most promising concept of electrically raised spacecraft appears to be the electrically propelled TV satellite extrapolated from TV-Sat. A.T.

N79-22190*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

PRIMARY ELECTRIC PROPULSION FOR FUTURE SPACE MISSIONS

David C. Byers, Fred F. Terdan, and Ira T. Myers 1979 45 p refs Presented at the Conf. on Adv. Technol. for Future Space Systems, Langley, Va., 8-11 May 1979; sponsored in part by AIAA

(NASA-TM-79141; E-9994) Avail: NTIS HC A03/MF A01 CSCL 20C

A general methodology is presented which allows prediction of the overall characteristics of thrust systems employing electron-bombardment ion thrusters. Elements of the thrust system are defined and their characteristics presented in a parametric fashion. Two system approaches are evaluated where power management and control elements and thruster characteristics were substantially different. For an assumed system approach, the methodology presented predicts overall system properties, such as input power and mass, when major mission and thrust system parameters, such as trip time and specific impulse, are assumed. Author

N79-23134# Aerospace Corp., El Segundo, Calif. Ivan A. Getting Labs.
MAGNETOSPHERIC AND IONOSPHERIC IMPACT OF LARGE-SCALE SPACE TRANSPORTATION WITH ION ENGINES Interim Report
Yam T. Chiu, Janet G. Luhmann, Barbara K. Ching, Michael Schulz, and Donald J. Boucher, Jr. Dec. 1978 45 p refs
(Contract F04700-78-M-2539)
(AD-A065482; TR-0079(4960-04)-3; SAMSO-TR-79-3) Avail: NTIS HC A03/MF A01 CSCL 21/3

Future large-scale space missions with payloads of = or - 10 million Kg (= or - 10,000 tons), such as the proposed Solar Power Satellite and Space Colonization, will probably require deep-space transportation systems based on the high specific-impulse ion engine. We note in this paper that the ion exhaust emissions corresponding to the proposed large payloads required for such missions may introduce basic modifications in the composition and dynamics of the ionosphere and magnetosphere. We identify some effects that such modifications may induce upon other spacesystems such as earth sensors, radiation belt dosage environment and signal scintillation due to beam-plasma interactions. We find that, because the space environment is tenuous, there is an interaction of sorts among such large-scale space systems and other earth-oriented space systems. The architectural design of such large-scale systems must take into account not only the efficient functioning of their primary mission objectives but also their influence upon the operations of other space systems. Author (GRA)

N79-24029*# Boeing Aerospace Co., Seattle, Wash.
PLASMA PARTICLE TRAJECTORIES AROUND SPACE-CRAFT PROPELLED BY ION THRUSTERS
H. B. Liemohn, R. L. Copeland, and W. M. Leavens *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 419-436 refs
Avail: NTIS HC A99/MF A01 CSCL 22B

The thruster plasma is assumed to be described by a collimated energetic beam and a cloud of ionized thermal propellant produced by charge-exchange. A simple adiabatic model is used to describe the expansion of these neutral plasmas away from the source. As the pressure falls, shielding currents dissipate, and the geomagnetic field takes control of the particles. In low earth orbit, it is concluded that the vehicle easily outruns its thruster plasma. At geosynchronous altitude, the local electric fields around high voltage surfaces collect return current from the thermal plasma that appears to be limited only by the available space charge. Results appropriate to proposed electric propulsion missions and the solar power satellite are presented and operational considerations are discussed. Author

N79-25129*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
LOW-THRUST CHEMICAL ORBIT TRANSFER PROPULSION
J. J. Pelouch, Jr. 1979 22 p refs Presented at the 15th Joint Propulsion Conf., Las Vegas, Nev., 18-20 Jun. 1979; sponsored by AIAA, Soc. of Automotive Engr., and ASME
(NASA-TM-79190; E-059) Avail: NTIS HC A02/MF A01 CSCL 22B

The need for large structures in high orbit is reported in terms of the many mission opportunities which require such structures. Mission and transportation options for large structures are presented, and it is shown that low-thrust propulsion is an enabling requirement for some missions and greatly enhancing to many others. Electric and low-thrust chemical propulsion are compared, and the need for an requirements of low-thrust chemical propulsion are discussed in terms of the interactions that are perceived to exist between the propulsion system and the large structure. S.E.S.

09
FLIGHT EXPERMENTS

Includes controlled experiments requiring high vacuum and zero G environment.

A79-38053 * # **LDEF transverse flat plate heat pipe experiment /S1005/.** G. A. Robinson, Jr. (NASA, Marshall Space Flight Center, Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Thermophysics Conference, 14th, Orlando, Fla., June 4-6, 1979, Paper 79-1077.* 7 p. Contract No. NAS8-31847.

The paper describes the Transverse Flat Plate Heat Pipe Experiment. A transverse flat plate heat pipe is a thermal control device that serves the dual function of temperature control and mounting base for electronic equipment. In its ultimate application, the pipe would be a lightweight structure member that could be configured in a platform or enclosure and provide temperature control for large space structures, flight experiments, equipment, etc. The objective of the LDEF flight experiment is to evaluate the zero-g performance of a number of transverse flat plate heat pipe modules. Performance will include: (1) the pipes transport capability, (2) temperature drop, and (3) ability to maintain temperature over varying duty cycles and environments. Performance degradation, if any, will be monitored over the length of the LDEF mission. This information is necessary if heat pipes are to be considered for system designs where they offer benefits not available with other thermal control techniques, such as minimum weight penalty, long-life heat pipe/structural members. (Author)

10
SOLAR POWER SATELLITE SYSTEM

Includes solar power satellite concepts with emphasis upon structures, materials, and controls.

A79-21265 # **An evolutionary solar power satellite program.** G. M. Hanley and W. R. Rhote (Rockwell International Corp., Satellite Systems Div., Downey, Calif.). *American Astronautical Society, Anniversary Conference, 25th, Houston, Tex., Oct. 30-Nov. 2, 1978, Paper 78-153.* 19 p.

An evolutionary solar power satellite (SPS) development plan was prepared to satisfy stated objectives. In this paper, effort is mainly directed to amplification of the technology advancement phase of the SPS development plan for the projected time frame 1980-1990. The discussion focuses on the microwave exploratory research program, the SPS power conversion/distribution and structures technology, the SPS orbital test platform evolution at low earth orbit and geosynchronous earth orbit, and the pilot plant demonstration phase. A well-focused ground test program supported by key Shuttle sortie experiments during the period 1980-1985 can lead to the evolution of the SPS orbital test platform during the latter part of the decade. Completion of the SPS technology advancement phase of SPS development in 1990 will provide the technical confidence to proceed with the full-scale pilot-plant demonstration phase. S.D.

A79-21266 # **A development strategy for the solar power satellite.** D. L. Gregory (Boeing Aerospace Co., Seattle, Wash.). *American Astronautical Society, Anniversary Conference, 25th, Houston, Tex., Oct. 30-Nov. 2, 1978, Paper 78-154.* 26 p.

An interdisciplinary study examined several problems associated with the solar power satellite (SPS) project, and the number of primary individual shuttle flights required to test the SPS concept is considered. It is suggested that a single sortie for launching a single large aperture satellite should be sufficient for providing proof of SPS concepts. The satellite and its role in studying developmental operations are described. After this project, which could be organized by about 1983, a later project, designed to assure success of major flight projects, would involve three shuttle flight sorties to study a structural beam 'machine', an orbital work station, and high power elements. M.L.

A79-31908 **Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978.** Conference sponsored by the Royal Aeronautical Society and American Institute of Aeronautics and Astronautics. London, Royal Aeronautical Society, 1979. 336 p. $35.

The energy research and development program of the U.S. is considered along with aspects of energy research and development on the basis of a UK view, prospects for reducing the fuel consumption of civil aircraft, the NASA aircraft energy efficiency program, aviation fuel from coal, commercial transports in the 1980s, the impact of aeronautical sciences on other modes of transport, and oil exploration from space. Attention is also given to the design and application of large wind turbine generators, off-shore multi-MW wind turbine system development as key to cost-effective wind energy for Sweden, a review of some critical aspects of satellite power systems, a preliminary assessment of the environmental impact of satellite power systems, European aspects of solar satellite power systems, and photovoltaics and solar thermal power systems. G.R.

A79-31919 # **Status of the SPS concept development and evaluation program.** F. A. Koomanoff (U.S. Department of Energy, Satellite Power Systems Projects Office, Washington, D.C.). In: Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978. London, Royal Aeronautical Society, 1979. 17 p.

The Satellite Power System (SPS) is designed to capture solar radiation in geosynchronous orbit and, by means of photovoltaics, convert the solar energy to electrical energy. The current status of the SPS program is discussed by describing the systems definition activities, environmental and societal assessment activities, and the comparative assessment directions. The organization and funding for these activities are also presented. It is concluded that to date no program stoppers have been found, however, many significant questions remain unanswered; questions which must be answered before the next steps may be reached in determining if SPS is indeed an energy option for mankind. G.R.

A79-31920 # **Solar Power Satellite systems definition.** G. R. Woodcock (Boeing Aerospace Co., Seattle, Wash.). In: Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978. London, Royal Aeronautical Society, 1979. 47 p.

A summary is provided of the results obtained in a detailed investigation of the technical and cost feasibility of Solar Power Satellites (SPS). Attention is given to SPS configuration options, the photovoltaic energy conversion, a recommended gallium arsenide satellite concept, the radiation degradation of solar cells, questions of power distribution, microwave power transmission, microwave generation technology, phase control, the power receiver system, ground-based power processing technology, laser power transmission, space transportation to low earth orbit, space-based construction and transportation operations, costing methods, cost analysis methodology, SPS cost ranges, economic analyses, resources requirements, and aspects of development and implementation. G.R.

A79-31921 # **A review of some critical aspects of satellite power systems.** I. V. Franklin (British Aerospace, Dynamics Group, Weybridge, Surrey, England) and A. W. Rudge (Electrical Research Association, Ltd., RF Technology Centre, Leatherhead, Surrey, England). In: Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978. London, Royal Aeronautical Society, 1979. 18 p. 13 refs.

Some critical aspects of the Solar Power Satellite (SPS) are considered. The basic concepts of the SPS are considered along with aspects of SPS delivery and construction systems, solar arrays, on board electrical power collection, costs, European activities, and questions of development strategy. The SPS microwave system is examined, taking into account basic operations and constraints, the baseline microwave system, major areas of uncertainty, and the space antenna. G.R.

A79-31923 # **European aspects of Solar Satellite Power systems.** M. Trella and K. K. Reinhartz (ESA, Noordwijk, Netherlands). In: Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978. London, Royal Aeronautical Society, 1979. 17 p. 18 refs.

It is pointed out that energy-related problems are potentially much more serious in Europe than in the U.S. The proposal is, therefore, made that European countries should investigate the prospects offered by the SPS as a future source of a part of the energy needed by them. An outline is presented of the specifically European problems which have to be investigated to evaluate the SPS concept. Possible European activities are examined, taking into account a concept evaluation, studies related to energy conversion, space construction and operation, power transmission and distribu-

tion, transportation, and the selection criteria for technological research. Program considerations and financial aspects are also explored. G.R.

A79-31925 * # The Solar Power Satellite concept - Towards the future. C. C. Kraft, Jr. (NASA, Johnson Space Center, Houston, Tex.). In: Energy and aerospace; Proceedings of the Anglo/American Conference, London, England, December 5-7, 1978. London, Royal Aeronautical Society, 1979. 12 p.

An evolutionary program phasing with respect to the development of a Solar Power Satellite (SPS) is considered, taking into account concept identification, concept evaluation, exploratory research, space technology projects, system development, and commercial operations. At the present time the concept evaluation phase of the program is underway. This phase is scheduled for completion in 1980. It will result in a recommendation as to whether the concept should be explored further and if so, in what manner. The recommendation will be based on technical feasibility, economic and environmental considerations, and comparisons with other potential systems of the future. It is premature to speculate on the conclusions and recommendations from the evaluation program as to whether the program should proceed to the next phase. G.R.

A79-32721 First steps to the Solar Power Satellite. P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.), G. M. Hanley (Rockwell International Corp., Downey, Calif.), R. H. Nansen (Boeing Aerospace Co., Seattle, Wash.), and R. L. Kline (Grumman Aerospace Corp., Bethpage, N.Y.). *IEEE Spectrum,* vol. 16, May 1979, p. 52-58.

The Solar Power Satellite (SPS) concept is described in the light of the so-called reference system, developed by the Department of Energy and NASA as a guideline for evaluating the SPS's technical, environmental, economic, and societal problems. The silicon solar-array design is considered, and it is noted that in order to extend the life of the cells the reference design features CO2 lasers mounted on the satellite to anneal the cells. The selected methods for transmitting power to earth, the questions of where and how to build the satellites and ground stations, and the projected design of the transportation system are also considered. The problems facing the SPS system are reviewed. A.A.

A79-34737 * # An economic analysis of a commercial approach to the design and fabrication of a space power system. Z. Putney (Solarex Corp., Rockville, Md.) and J. Been (NASA, Lewis Research Center, Cleveland, Ohio). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 300-305. 6 refs. (AIAA 79-0914)

This paper discusses a commercial approach to the design and fabrication of an economical space power system. With the advent of the space shuttle, steps can be taken to back away from the presently used space qualified approach in order to reduce cost of space hardware by incorporating, where possible, commercial design, fabrication, and quality assurance methods. Cost reductions are projected through the conceptual design of a 2 kW space power system built with the capability for having serviceability. The approach to system costing that has been used takes into account both the constraints of operation in space and commercial production engineering approaches. The cost of this power system reflects a variety of cost/benefit tradeoffs that would reduce system cost as a function of system reliability requirements, complexity, and the impact of rigid specifications. A breakdown of the system design, documentation, fabrication and reliability and quality assurance cost estimates are detailed. (Author)

A79-34846 # New methods for the conversion of solar energy to R. F. and laser power. J. W. Freeman, W. B. Colson, and S. Simons (Rice University, Houston, Tex.). *Princeton University and American Institute of Aeronautics and Astronautics, Conference on Space Manufacturing Facilities, 4th, Princeton University, Princeton, N.J., May 14-17, 1979, AIAA Paper 791416.* 7 p. 8 refs.

This paper discusses two new devices which may have application to space deployed solar energy conversion and transmission systems, the photoklystron and the free electron laser. The photoklystron converts solar energy directly to RF radiation. It operates on the principle of the klystron with the cathode replaced by a photoemitting surface. We have tested a model which oscillates at 30 MHz. This laboratory model requires two low-voltage bias voltages which can be supplied by dc solar cells. Concepts for a self-biasing device are also being considered. The photoklystron is expected to be easier and less expensive to manufacture than solid state solar cells. A photoklystron array could replace the high voltage solar cell array, slipring and klystron transmitter in the SPS. The second device, the free electron laser (FEL), converts energy from a relativistic electron beam to narrow band electromagnetic energy, tuneable from the infrared to the ultraviolet. Because the lasing electrons are not bound in atomic energy levels the ultimate efficiency of the FEL is expected to exceed that of conventional lasers, possibly making lasers a practical means of energy conversion and transmission in space systems. (Author)

A79-35488 The development of solar power satellites (La mise au point de satellites à énergie solaire). P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.). *Revue de l'Energie,* vol. 30, Mar. 1979, p. 246-266. In French. (Translation).

A 5-GW solar power satellite employing silicon or gallium arsenide photovoltaic cells is being considered for development. Power transmission schemes and the transport system needed to orbit the materials and personnel for the solar power satellite are discussed. Cost projections, technological problems associated with receiving antennas, and possible environmental effects of the solar power satellite also receive attention. J.M.B.

A79-37842 International Conference on Future Energy Concepts, London, England, January 30-February 1, 1979, Proceedings. Conference sponsored by the Institution of Electrical Engineers. London, Institution of Electrical Engineers (IEE Conference Publication, No. 171),1979. 460 p. $46.

Papers are presented on solar energy utilization, wave power experiments, geothermal energy, tidal power, MHD power generation, wind energy systems, and hydrogen energy. Particular consideration is given to windpower generation on a large scale, the prospects of a biological-photochemical approach to the utilization of solar energy, tidal and river current energy systems, and satellite solar power stations. B.J.

A79-37844 Satellite solar power stations - Current status and prospects. P. O. Collins (Imperial College of Science and Technology, London, England). In: International Conference on Future Energy Concepts, London, England, January 30-February 1, 1979, Proceedings. London, Institution of Electrical Engineers, 1979, p. 21-25. 28 refs.

A brief review of the satellite solar power station concept is presented with attention given to technical environmental aspects. Cost estimates are discussed and consideration is given to the possible use of extraterrestrial materials and to UK interest in the project. B.J.

A79-38201 # Space Laser Power System. W. S. Jones (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). *American Institute of Aeronautics and Astronautics, Terrestrial Energy Systems Conference, Orlando, Fla., June 4-6, 1979, Paper 79-1013.* 7 p. 12 refs.

The Space Laser Power System (SLPS) concept developed for NASA requires only a few acres of protected area around the ground receiver in contrast to tens of thousands of acres for the microwave beam of the Solar Power Satellite (SPS) concept, although the SLPS must include features to insure safe operations. For instance, in order to overcome the inability to penetrate heavy clouds (the major inconvenience), multiple ground stations and switching to clear sites is suggested. A description of different parts of the SLPS is presented, with consideration given to the electrical discharge laser (EDL) and the solar-pumped laser (SPL) space options, also noting some systems concepts. It is shown that the overall efficiency from solar energy in space to electrical output on the ground for the microwave SPS is 7.3%, for the EDL system is 6.4%, and for the SPL system is 9.4%. V.T.

A79-38202 * # **Solar-pumped lasers for space power transmission.** R. Taussig, C. Bruzzone, L. Nelson, D. Quimby (Mathematical Sciences Northwest, Inc., Bellevue, Wash.), and W. Christiansen (Washington, University, Seattle, Wash.). *American Institute of Aeronautics and Astronautics, Terrestrial Energy Systems Conference, Orlando, Fla., June 4-6, 1979, Paper 79-1015.* 18 p. 40 refs. Contract No. NAS3-21134.

Multi-Megawatt CW solar-pumped lasers appear to be technologically feasible for space power transmission in the 1990s time frame. A new concept for a solar-pumped laser is presented which utilizes an intermediate black body cavity to provide a uniform optical pumping environment for the lasant, either CO or CO2. Reradiation losses are minimized with resulting high efficiency operation. A 1 MW output laser may weigh as little as 8000 kg including solar collector, black body cavity, laser cavity and ducts, pumps, power systems and waste heat radiator. The efficiency of such a system will be on the order of 10 to 20%. Details of the new concept, laser design, comparison to competing solar-powered lasers and applications to a laser solar power satellite (SPS) concept are presented. (Author)

A79-38374 **Solar power satellites - Microwaves deliver the power.** W. C. Brown (Raytheon Co., Microwave and Power Tube Div., Waltham, Mass.). *IEEE Spectrum,* vol. 16, June 1979, p. 36-42.

While microwave power transmission from the Solar Power Satellite (SPS) network provides such advantages as availability of the sun's energy for more than 99% of the year, supply of five GW of power from each SPS and dc-to-dc transmission efficiency of more than 60%, there are three possible environmental problems associated with the SPS system: radio frequency interference (RFI), local heating of the ionosphere, and possibly harmful biological effects. The RFI and ionospheric problems are being studied by DOE and safety features, such as a pilot beam for the transmitting antenna to track are planned, to keep microwave beams from wandering off target and affecting people. The microwave transmission system envisioned in the DOE/NASA reference design comprises three parts: 1) The conversion of dc power to microwave power. 2) The formation and control of microwave beams and 3) The collection of the microwave energy and its conversion into dc energy. The design uses the linear-beam tube in its klystron format; however, the crossed-field device in either magnetron-directional-amplifier or amplitron is still an option for the final design. V.T.

A79-40490 * # **New energy conversion techniques in space, applicable to propulsion.** A. Hertzberg (Washington, University, Seattle, Wash.) and K. C. Sun (Lockheed Research Laboratories, Palo Alto, Calif.). *AIAA, SAE, and ASME, Joint Propulsion Conference, 15th, Las Vegas, Nev., June 18-20, 1979, AIAA Paper 79-1338.* 43 p. 25 refs. Grant No. NGL-48-002-044.

The powering of aircraft with laser energy from a solar power satellite may be a promising new approach to the critical problem of the rising cost of fuel for aircraft transportation systems. The result is a nearly fuelless, pollution-free flight transportation system which is cost-competitive with the fuel-conservative airplane of the future. The major components of this flight system include a laser power satellite, relay satellites, laser-powered turbofans and a conventional airframe. The relay satellites are orbiting optical systems which intercept the beam from a power satellite and refocus and redirect the beam to its next target. (Author)

A79-44160 **Energy analysis of the Solar Power Satellite.** R. A. Herendeen, T. Kary, and J. Rebitzer (Illinois, University, Urbana, Ill.). *Science,* vol. 205, Aug. 3, 1979, p. 451-454. 25 refs.

The energy requirements to build and operate the proposed Solar Power Satellite are evaluated and compared with the energy it produces. Because the technology is so speculative, uncertainty is explicitly accounted for. For a proposed 10-gigawatt satellite system, the energy ratio, defined as the electrical energy produced divided by the primary nonrenewable energy required over the lifetime of the system, is of order 2, where a ratio of 1 indicates the energy breakeven point. This is significantly below the energy ratio of today's electricity technologies such as light-water nuclear or coal-fired electric plants. (Author)

A79-44249 **Solar power satellite ground stations.** R. Andryczyk, P. Foldes, J. Chestek (General Electric Co., Space Div., Valley Forge, Pa.), and B. M. Kaupang (General Electric Co., Schnectady, N.Y.). *IEEE Spectrum,* vol. 16, July 1979, p. 51-55.

The main ground installation for a solar power satellite system, employing a low-gain 10 km diameter rectifying antenna (rectenna), a medium-voltage dc power-collecting grid, dc/ac converters, and a high-voltage ac power-collecting grid, is examined. It is found that the rectenna can collect 5 GW of power at 2.45 GHz at a theoretical maximum power density of 24.3 mW/cm squared, if minimal atmospheric attenuation is assumed. The size and configuration of the rectenna are studied and characteristics, including field distribution (Gaussian), total transmit power (7.1249 GW), edge taper (-8.8 dB) and nominal dimensions (NS 11.48 km and NE 9.4 km), are noted. The dipole assembly of the rectenna, containing a circuit that matches the impedance of the dipole to the impedance of the diode circuit is analyzed and specific detail is given to the study of the rectenna's power-collecting system that uses several thousand panels to make up a 500-kW module. It is concluded that the most important characteristics of the rectenna are the availability of its power output and longevity; the expected overhaul is only once every thirty years. C.F.W.

A79-44277 # **The solar power satellite concept.** P. E. Glaser (Arthur D. Little, Inc., Cambridge, Mass.). *AIAA Student Journal,* vol. 17, Summer 1979, p. 32-41. 25 refs.

A method to utilize solar energy through solar power satellites (SPS) is presented. The electricity produced by solar energy conversion will be fed to microwave generators forming part of a planar, phased-array transmitting antenna, which in turn is designed to direct a microwave beam to one or more receiving antennas. Variations in solar power output due to eclipses, equinox periods and other predictable interruptions, are expected to range from 1.309 kW/sq m to 1.399 kW/sq m. Technological options for solar energy conversion, including photovoltaic and thermal-electric processes are described. Attention is also given to the assembly and maintenance of SPS, economic and environmental implications, as well as microwave biological effects and other impacts, which include thermal pollution, land despoilment and resource consumption. C.F.W.

A79-46699 * # **Effects of plasma sheath on solar power satellite array.** L. W. Parker (Lee W. Parker, Inc., Concord, Mass.). *American Institute of Aeronautics and Astronautics, Fluid and Plasma Dynamics Conference, 12th, Williamsburg, Va., July 23-25, 1979, Paper 79-1507.* 8 p. 11 refs. NASA-supported research.

The structure of the plasma sheath and equilibrium voltage distribution of a high-power solar array governs various kinds of plasma-interaction phenomena and array losses. Sheath effects of a linearly-connected array are investigated for GEO. Although the array may be large, the thin-sheath-limit analysis may be invalid, necessitating numerical methods. Three-dimensional computer calculations show that potential barriers and over-lapping sheaths can occur, i.e., structures not predictable under the thin-sheath-limit analysis, but nevertheless controlling the distribution of plasma currents impacting on the array. (Author)

A79-48026 **Energy for the year 2000 - The SPS concept (Energie für das Jahr 2000 - Das SPS-Konzept).** G. Tschulena. *Nachrichten Elektronik,* vol. 33, Aug. 1979, p. 249-254. 7 refs. In German.

The solar power satellite (SPS) system is examined. Different aspects of the project are discussed including the energy conversion technology such as solar cells of different compounds and thermoelectric converters. Also covered are the microwave transmission system, and environmental concerns such as biological effects and the dispersion of microwaves. Consideration is also given to realization of the project through the Space Shuttle. Finally, the development program of the SPS project is discussed. M.E.P.

A79-50399 **Solar power satellite - Putting it together.** R. W. Johnson (Grumman Aerospace Corp., Bethpage, N.Y.). *IEEE Spectrum,* vol. 16, Sept. 1979, p. 37-40.

The problems of constructing a solar power satellite in earth orbit are surveyed. Consideration is given to such points as the need for an assembly line in space, for lightweight yet strong and durable materials, for a completely new heavy lift launch vehicle and for special manipulative tools for assembly work. Advanced composite materials are discussed as well as the question of whether to build in low or high earth orbit. Construction techniques described include an automatic beam making machine and remote work stations. Finally, it is concluded that the development of construction techniques for the SPS will have other uses which will reduce the R&D costs chargeable to the solar power satellite. M.E.P.

A79-51891 * # **Results from Symposium on Future Orbital Power Systems Technology Requirements.** S. Gorland (NASA, Lewis Research Center, Cleveland, Ohio). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings. Volume 2. Washington, D.C., American Chemical Society, 1979, p. 1203-1206.

Technology deficiencies, adequacy of current programs, and recommendations for reducing the testing and risks involved in future orbital energy systems made at the NASA Symposium are summarized. Photovoltaic space power system problems, including structural dynamics and attitude control problems due to solar array flexing; solar cell radiation resistance, manufacturing capability, and cost reduction; solar arrays including inflatable arrays, spectrum selection to increase efficiency, and polymer coatings for cells; battery technology; the endurance data base for fuel cell and electrolysis technology, and power management were discussed. Other topics considered were laser/microwave power transmission, thermal management, nuclear power systems, and environmental interactions. It was concluded that a 'front end' system study is needed in each area and current programs for multi-hundred-kW power systems are underscoped. A.T.

A79-51941 * **Computer modeling for a space power transmission system.** S. M. Rathjen (Boeing Aerospace Co., Seattle, Wash.) and D. K. Reynolds (Washington, University, Seattle, Wash.). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings. Volume 2. Washington, D.C., American Chemical Society, 1979, p. 1480-1485. 12 refs. Contracts No. NAS9-15636; No. NAS9-15196.

The paper summarizes the development of a computer program that simulates the performance of a large phased array antenna composed of 7220 smaller subarrays, each made up of klystron modules which act as individual radiators. The purpose of this program is to: (1) study the far-field pattern near the rectenna, (2) calculate the beam efficiency, and (3) observe the grating lobe behavior. Attention is given to the computer program which consists of a main program and four subroutines, as well as to the system configurations. The effects of amplitude, phase and random subarray failures are examined and an error budget was specified for 10 to the 0 phase error, + or - 1 dB amplitude error, and a 2% random failure rate. C.F.W.

A79-51943 **The technology base for the microwave power transmission system in the SPS.** W. C. Brown (Raytheon Co., Waltham, Mass.). In: Intersociety Energy Conversion Engineering Conference, 14th, Boston, Mass., August 5-10, 1979, Proceedings. Volume 2. Washington, D.C., American Chemical Society, 1979, p. 1492-1499. 13 refs.

The microwave power transmission system in the Solar Power Satellite (SPS) is reviewed in terms of the existing technology base. This technology base consists of: (1) the experience that has been obtained from complete transmission systems including the interconversion of dc and microwave energy at both ends of the system and all of the interfaces between various parts of the system; (2) the efficient conversion of dc power into microwave power; (3) the microwave beam link itself; and (4) the efficient collection of microwave power at the receiving end of the link and its conversion back into dc power. Special emphasis is placed upon recent additions to this technology base and also upon the critical nature of some of the microwave technology that is needed to meet the SPS requirements. (Author)

A79-53301 **Superlight rotating reflectors in space.** A. V. Luk'ianov (Moskovskii Gosudarstvennyi Universitet, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-112.* 14 p. 10 refs.

The use of large mirror reflectors in space to control solar and electromagnetic radiation with specific mass of order of 1 gm/sq m or less is examined. Such reflectors may be used in space energetics for concentration of solar energy for its conversion into a microwave beam and transmission to earth, for illuminating the earth surface with reflected sunlight, weather control, and research. Design and construction of the reflector, its main parameters including angular and rotative speed, and the control of rotation, precession, and nutation, and the position control in space are discussed. The control of its orientation and space position is performed with solar energy and light pressure, and the film strength permits concentrators with a radii of several kilometers and nearly flat reflectors for lighting application with a radii of several hundred meters. More than a hundred reflectors of 600 m diameter can be assembled at a station at the 1000 km height yearly, but a difficult problem of superthin film mass production and assembly technology problems must be solved to realize this program. A.T.

A79-53302 * **Cost comparisons for the use of nonterrestrial materials in space manufacturing of large structures.** E. H. Bock and R. C. Risley (General Dynamics Corp., Convair Div., San Diego, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-115.* 24 p. 16 refs. NASA-sponsored research.

This paper presents results of a study sponsored by NASA to evaluate the relative merits of constructing solar power satellites (SPS) using resources obtained from the earth and from the moon. Three representative lunar resources utilization (LRU) concepts are developed and compared with a previously defined earth baseline

concept. Economic assessment of the alternatives includes cost determination, economic threshold sensitivity to manufacturing cost variations, cost uncertainties, program funding schedule, and present value of costs. Results indicate that LRU for space construction is competitive with the earth baseline approach for a program requiring 100,000 metric tons per year of completed satellites. LRU can reduce earth-launched cargo requirements to less than 10% of that needed to build satellites exclusively from earth materials. LRU is potentially more cost-effective than earth-derived material utilization, due to significant reductions in both transportation and manufacturing costs. Because of uncertainties, cost-effectiveness cannot be ascertained with great confidence. The probability of LRU attaining a lower total program cost within the 30-year program appears to range from 57 to 93%. (Author)

A79-53334 **Solar power satellites for Europe.** J. Ruth and W. Westphal (Berlin, Technische Universität, Berlin, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-173.* 12 p. 6 refs.

The potential utilization of Solar Power Satellites (SPS) as baseload powerplants for Western European countries is studied. Attention is given to significant differences with the USA in factors such as geographical, political, organizational, orbital, and industrial. Among the problems discussed which must be solved prior to full scale SPS development is the impact on the environment. Finally recommendations are made and conclude that the analysis of specific European problems has to be extended and refined, a joint group of US and European planners and engineers must work out the specifications for a cooperation in a technology program after 1982, and a specific European experimental program on the impacts of SPS installation and operation on the environment has to be implemented. M.E.P.

A79-53335 **European technology applicable to Solar Power Satellite Systems /SPS/.** H. Stoewer (ESA, System Engineering Dept., Noordwijk, Netherlands), B. Tilgner (ESA, Technology, Industry and Infrastructure Dept., Paris, France), and D. Kassing (ESA, Spacecraft Power Supplies Div., Noordwijk, Netherlands). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-174.* 23 p. 14 refs.

The paper reviews European space technology activities that have potential for application in an SPS program. Existing and developing European space technologies are compared with the expected requirements of a study assessment and early key technology verification investigation for the SPS concept. It is shown that a number of existing European space technologies and the results of current development efforts apply well to this. Topics discussed include solar energy conversion, electrical energy conversion, electrical to microwave conversion, microwave power transmission, space structures, attitude and orbit control, thermal control, and ground receiver stations. M.E.P.

A79-53336 **Satellite solar power station designs with concentrators and radiating control.** A. V. Luk'ianov (Moskovskii Gosudarstvennyi Universitet, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-176.* 6 p. 6 refs.

The paper investigates the application of superlight rotating parabolic concentrators for space energetics. The total mass of all high temperature converters considered, does not exceed that of the transmitting antenna. Attention is given to a design with two concentrators weighing 30 Mg, which offers the possibility of control of mast orientation by using thin movable mirrors of tungsten or other thermoresistant material in the concentrator foci. In this manner reflection of an insignificant part of concentrated energy in the corresponding direction will create the necessary thrust. Also discussed are a satellite power station (SSPS) with numerous concentrators and SSPS with solar cells. Here eight adjustable mirrors situated along the periphery could work as concentrators as well as corrections engines. M.E.P.

A79-53337 **A space power station without movable parts.** M. Pospisil (Ceskoslovenska Akademie Ved, Astronomicky Ustav, Ondrejov, Czechoslovakia). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-177.* 10 p.

An area of suitable shape could be used as a receiver of solar radiation ('outer' surface) and a microwave antenna ('inner' surface). Elimination of the necessity to revolve the panels with cells, delivery of power according to the average demand and other features of this SPS concept are discussed. (Author)

A79-53359 **Use of a large space structure as an orbital depot for hazardous wastes.** P. Natenbruk (ERNO Raumfahrttechnik GmbH, Bremen, West Germany). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-209.* 41 p.

Some concepts are presented for the use of a large orbital space depot for hazardous wastes. Among the advantages cited for such a concept are: safe storage of waste over a very long time, insensitivity to geological changes on earth, no pollution risk of life environment, and low sensitivity to sabotage. Factors affecting the implementation of such a project include: public acceptance, technical definition, program implementation, legal issues, and organizational structure. Among the conclusions it is noted that high absolute costs of concept realization should not be a deterrent, since they must be compared to total losses/costs associated with keeping wastes on earth. M.E.P.

A79-53487 **A power transmission concept for a European SPS system.** R. A. Henderson (British Aerospace, Dynamics Group, Bristol, England). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper.* 14 p. 15 refs.

A hybrid SPS system is proposed in which solar power is collected in geosynchronous orbit and transmitted by a concentrated laser beam to a receiver mounted on a 2.6-km-diam rigid balloon stationed at approximately 30-km altitude; power is converted to microwave energy and beamed to the ground to multiple rectennae which are significantly reduced from those of the direct microwave transmission to ground concept. Waste heat from the energy conversion process would provide power to maintain a stable balloon platform which could perform other functions related to earth observation and communications. (Author)

N79-21538*# National Aeronautics and Space Administration, Washington, D. C.

SATELLITE POWER SYSTEM: CONCEPT DEVELOPMENT AND EVALUATION PROGRAM. REFERENCE SYSTEM REPORT

Jan. 1979 321 p refs Prepared in cooperation with DOE, Washington, D. C.
(NASA-TM-79762; DOE/ER-0023) Avail: NTIS HC A14/MF A01 CSCL 10B

The Satellite Power System (SPS) Reference System is discussed and the technical and operational information required in support of environmental, socioeconomic, and comparative assessment studies are emphasized. The reference System concept features a gallium-aluminum-arsenide, and silicon solar cell options. Other aspects of an SPS are the construction of bases in space, launch and mission control bases on earth, and fleets of various transportation vehicles to support the construction and maintenance operations of the satellites. M.M.M.

N79-22193*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
AN ECONOMIC ANALYSIS OF A COMMERCIAL APPROACH TO THE DESIGN AND FABRICATION OF A SPACE POWER SYSTEM
Zimri Putney (Solarex Corp., Rockville, Md.) and Julian Been 1979 8 p refs Presented at the Conf. on Adv. Technol. for Future Space Systems, Hampton, 8-11 May 1979; sponsored by AIAA
(NASA-TM-79153; E-1009) Avail: NTIS HC A02/MF A01 CSCL 10A

A commercial approach to the design and fabrication of an economical space power system is presented. Cost reductions are projected through the conceptual design of a 2 kW space power system built with the capability for having serviceability. The approach to system costing that is used takes into account both the constraints of operation in space and commercial production engineering approaches. The cost of this power system reflects a variety of cost/benefit tradeoffs that would reduce system cost as a function of system reliability requirements, complexity, and the impact of rigid specifications. A breakdown of the system design, documentation, fabrication, and reliability and quality assurance cost estimates are detailed. J.M.S.

N79-22261# Vermont Univ., Burlington. Dept. of Chemistry.
NEW HIGHLY CONDUCTING COORDINATION COMPOUNDS
D. B. Brown, K. Carneiro, P. Day, B. Hoffman, H. J. Keller, W. A. Little, A. E. Underhill, and J. M. Williams 17 Jan. 1979 11 p Submitted for publication
(Contract N00014-75-C-0756)
(AD-A064735; TR-11) Avail: NTIS HC A02/MF A01 CSCL 07/3

Structural features of coordination compounds which lead to high electrical conductivity are examined. Certain features are shown to be necessary for high conductivity, and suggestions are made concerning future synthetic efforts required in the search for molecular metals. Author (GRA)

N79-22616*# Boeing Aerospace Co., Seattle, Wash.
SYSTEMS DEFINITION SPACE BASED POWER CONVERSION SYSTEMS: EXECUTIVE SUMMARY Final Report
1977 29 p refs
(Contract NAS8-31628)
(NASA-CR-150209; D180-20309-1) Avail: NTIS HC A03/MF A01 CSCL 10B

Potential space-located systems for the generation of electrical power for use on earth were investigated. These systems were of three basic types: (1) systems producing electrical power from solar energy; (2) systems producing electrical power from nuclear reactors; (3) systems for augmenting ground-based solar power plants by orbital sunlight reflectors. Configurations implementing these concepts were developed through an optimization process intended to yield the lowest cost for each. A complete program was developed for each concept, identifying required production rates, quantities of launches, required facilities, etc. Each program was costed in order to provide the electric power cost appropriate to each concept. G.Y.

N79-22617*# ECON, Inc., Princeton, N. J.
SPACE-BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 1: EXECUTIVE SUMMARY Final Report, 30 Sep. 1976 - 31 Mar. 1977
31 Mar. 1977 49 p 5 Vol.
(Contract NAS8-31308)
(NASA-CR-150294; Rept-77-145-1-Vol-1) Avail: NTIS HC A03/MF A01 CSCL 10B

The research concerning space-based solar power conversion and delivery systems is summarized. The potential concepts for a photovoltaic satellite solar power system was studied with emphasis on ground output power levels of 5,000 MW and 10,000 MW. A power relay satellite, and certain aspects of the economics of these systems were also studied. A second study phase examined in greater depth the technical and economic aspects of satellite solar power systems. Throughout this study, the focus was on the economics of satellite solar power. The results indicate technical feasibility of the concept, and provide a preliminary economic justification for the first phase of a substantial development program. A development program containing test satellites is recommended. Also, development of alternative solar cell materials (other than silicon) is recommended. F.O.S.

N79-22618*# Grumman Aerospace Corp., Bethpage, N.Y.
SPACE-BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 2: ENGINEERING ANALYSIS Final Report
31 Mar. 1977 264 p refs Prepared for ECON, Inc., Princeton, N. J.
(Contract NAS8-31308)
(NASA-CR-150295) Avail: NTIS HC A12/MF A01 CSCL 10B

The technical and economic feasibility of Satellite Solar Power Systems was studied with emphasis on the analysis and definition of an integrated strawman configuration concept, from which credible cost data could be estimated. Specifically, system concepts for each of the major subprogram areas were formulated, analyzed, and iterated to the degree necessary for establishing an overall, workable baseline system design. Cost data were estimated for the baseline and used to conduct economic analyses. The baseline concept selected was a 5-GW crystal silicon truss-type photovoltaic configuration, which represented the most mature concept available. The overall results and major findings, and the results of technical analyses performed during the final phase of the study efforts are reported. F.O.S.

N79-22619*# Raytheon Co., Wayland, Mass. Equipment Div.
SPACE-BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 3: MICROWAVE POWER TRANSMISSION STUDIES Final Report
1 Mar. 1977 195 p refs Prepared for ECON, Inc., Princeton, N. J.
(Contract NAS8-31308)
(NASA-CR-150296) Avail: NTIS HC A09/MF A01 CSCL 10B

The Microwave Fower Beam Ionosphere effects and critical interfaces between th Microwave Power Transmission System (MPTS) and the Satellite were studied as part of the NASA/MSFC continuing research on the feasibility of power transmission from geosynchronous orbit. Theoretical predications of ionospheric modifications produced by the direct interaction of the MPTS on the earth's upper atmosphere are used to determine their impact on the performance of the Microwave Power Beam and Pilot Beam System as well as on other RF systems effected by the ionosphere. A technology program to quantitatively define these interactions is developed. Critical interface areas between the MPTS and the sateilite which could have a major impact on cost and performance of the power system are idenfified and analyzed. The areas selected include: use of either a 20 kV versus 40 kV Amplitron, thermal blockage effects of Amplitron heat radiation by the satellite structure, effect of dielectric carry-through structure on power beam, and effect of material sublimation on performance of the Amplitron in Geosynchronous Orbit. F.O.S.

N79-22620*# Little (Arthur D.), Inc., Cambridge, Mass.
SPACE-BASED SOLAR POWER CONVERSION AND DELIVERY SYSTEMS STUDY. VOLUME 4: ENERGY CONVERSION SYSTEMS STUDIES Final Report
29 Mar. 1977 74 p refs Prepared for ECON, Inc., Princeton, N. J.
(Contract NAS8-31308)
(NASA-CR-150297; C-78127-Vol-4) Avail: NTIS HC A04/MF A01 CSCL 10B

Solar cells and optical configurations for the SSPS were examined. In this task, three specific solar cell materials were examined: single crystal silicon, single crystal gallium arsenide, and polycrystalline cadmium sulfide. The comparison of the three different cells on the basis of a subsystem parametric cost per kW of SSPS-generated power at the terrestrial utility interface showed that gallium arsenide was the most promising solar cell material at high concentration ratios. The most promising solar cell material with no concentration, was dependent upon the particular combination of parameters representing cost, mass and performance that were chosen to represent each cell in this deterministic comparative analysis. The potential for mass production, based on the projections of the present state-of-the-art would tend to favor cadmium sulfide in lieu of single crystal silicon or gallium arsenide solar cells. F.O.S.

N79-22632*# Rockwell International Corp., Downey, Calif. Space Systems Group.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY EXHIBIT C. VOLUME 3: EXPERIMENTAL VERIFICATION DEFINITION Final Report
Mar. 1979 152 p
(Contract NAS8-32475)
(NASA-CR-161214; SSD-79-0010-3) Avail: NTIS HC A08/MF A01 CSCL 10B

An environmentally oriented microwave technology exploratory research program aimed at reducing the uncertainty associated with microwave power system critical technical issues is described. Topics discussed include: (1) Solar Power Satellite System (SPS) development plan elements; (2) critical technology issues related to the SPS preliminary reference configuration; (3) pilot plant to demonstrate commercial viability of the SPS system; and (4) research areas required to demonstrate feasibility of the SPS system. Progress in the development of advanced GaAs solar cells is reported along with a power distribution subsystem. J.M.S.

N79-22633*# Rockwell International Corp., Downey, Calif. Space Systems Group.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 5: SPECIAL EMPHASIS STUDIES Final Report
G. Hanley Mar. 1979 265 p refs
(Contract NAS8-32475)
(NASA-CR-161215; SSD-79-0010-5) Avail: NTIS HC A12/MF A01 CSCL 10B

Specific areas were analyzed and identified as high priority for more in-depth analysis. These areas were: (1) rectenna constructability; (2) satellite constructability; (3) support systems constructability; (4) space environmental analysis, and (5) special end-to-end analyses. Baseline requirements specified coplanar solar blankets and an end mounted antenna, utilizing either GaAlAs solar cells and employing a CR of 2, or Si cells. Several configurations were analyzed. Utilizing the preferred configuration as a baseline, a satellite construction base was defined, precursor operations incident to establishment of orbital support facilities identified, and the satellite construction sequence and procedures developed. Since the baseline specifies sixty instead of one hundred and twenty satellites to be constructed in a thirty year period, mass flow to orbit requirements were revised and new traffic models established. Launch site requirements (exclusive of actual launch operations) in terms of manpower and building space were defined. J.M.S.

N79-22634*# Rockwell International Corp., Downey, Calif. Space Systems Group.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 6: IN-DEPTH ELEMENT INVESTIGATION Final Report
G. Hanley Mar. 1979 97 p refs
(Contract NAS8-32475)
(NASA-CR-161216; SSD-79-0010-6) Avail: NTIS HC A05/MF A01 CSCL 10B

Computer assisted design of a gallium arsenide solid state dc-to-RF converter with supportive fabrication data was investigated. Specific tasks performed include: computer program checkout; amplifier comparisons; computer design analysis of GaSa solar cells; and GaAs diode evaluation. Results obtained in the design and evaluation of transistors for the microwave space power system are presented. J.M.S.

N79-23483*# Boeing Aerospace Co., Seattle, Wash.
SYSTEMS DEFINITION SPACE-BASED POWER CONVERSION SYSTEMS Final Report, 8 Jun. 1975 - 30 Nov. 1976
30 Nov. 1976 95 p refs Prepared in cooperation with Garrett Corp., Los Angeles, and Thermo Electron Corp.
(Contract NAS8-31628)
(NASA-CR-150268; D180-20309-2) Avail: NTIS HC A05/MF A01 CSCL 10B

Potential space-located systems for the generation of electrical power for use on Earth are discussed and include: (1) systems producing electrical power from solar energy; (2) systems producing electrical power from nuclear reactors; and (3) systems for augmenting ground-based solar power plants by orbital sunlight reflectors. Systems (1) and (2) would utilize a microwave beam system to transmit their output to Earth. Configurations implementing these concepts were developed through an optimization process intended to yield the lowest cost for each. A complete program was developed for each concept, identifying required production rates, quantities of launches, required facilities, etc. Each program was costed in order to provide the electric power cost appropriate to each concept. A.R.H.

N79-23484*# Rockwell International Corp., Downey, Calif. Satellite Systems Div.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 1: EXECUTIVE SUMMARY Final Report
G. M. Hanley Mar. 1979 66 p refs 7 Vol.
(Contract NAS8-32475)
(NASA-CR-161218; SSD-79-0010-1-Vol-1) Avail: NTIS HC A04/MF A01 CSCL 10B

The Department of Energy (DOE) is currently conducting an evaluation of approaches to provide energy to meet demands in the post-2000 time period. The Satellite Power System (SPS) is a candidate for producing significant quantities of base-load power using solar energy as the source. The SPS concept is illustrated for a solar photovoltaic concept. A satellite, located at geosynchronous orbit, converts solar energy to dc electrical energy using large solar arrays. This study is a continuing effort to provide system definition data to aid in the evaluation of the SPS concept. G.Y.

N79-23485*# Rockwell International Corp., Downey, Calif. Satellite Systems Div.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 2, PART 1: SYSTEM ENGINEERING Final Report
G. M. Hanley Mar. 1979 257 p refs 7 Vol.
(Contract NAS8-32475)
(NASA-CR-161219; SSD-79-0010-2-1-Vol-2-Pt-1) Avail: NTIS HC A12/MF A01 CSCL 10B

Volume 2, Part 1, of a seven volume report is presented. Part 1 encompasses Satellite Power Systems (SPS) systems engineering aspects and is divided into three sections. The first section presents descriptions of the various candidate concepts considered and conclusions and recommendations for a preferred concept. The second section presents a summary of results of the various trade studies and analysis conducted during the course of the study. The third section describes the Photovoltaic Satellite Based Satellite Power System (SPS) Point Design as it was defined through studies performed during the period January 1977 through March 1979. G.Y.

N79-23486*# Rockwell International Corp., Downey, Calif. Satellite Systems Div.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 2, PART 2: SYSTEM ENGINEERING, COST AND PROGRAMMATICS Final Report
G. M. Hanley Mar. 1979 113 p refs 7 Vol.
(Contract NAS8-32475)
(NASA-CR-161220; SSD-79-0010-2-2-Vol-2-Pt-2) Avail: NTIS HC A06/MF A01 CSCL 10B

Volume 2, Part 2, of a seven volume Satellite Power Systems (SPS) report is presented. Part 2 covers cost and programmatics and is divided into four sections. The first section gives illustrations of the SPS reference satellite and rectenna concept, and an overall scenario for SPS space transportation involvement. The second section presents SPS program plans for the implementation of PHASE C/D activities. These plans describe SPS program schedules and networks, critical items of systems evolution/technology development, and the natural resources analysis. The fourth section presents summary comments on the methods and rationale followed in arriving at the results documented. Suggestions are also provided in those areas where further analysis or evaluation will enhance SPS cost and programmatic definitions. G.Y.

N79-23487*# Rockwell International Corp., Downey, Calif. Satellite Systems Div.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 2, PART 2: SYSTEM ENGINEERING, COST AND PROGRAMMATICS, APPENDIXES Final Report
G. M. Hanley Mar. 1979 318 p refs 7 Vol.
(Contract NAS8-32475)
(NASA-CR-161221; SSD-79-0010-2-2-Vol-2-Pt-2-APP) Avail: NTIS HC A14/MF A01 CSCL 10B

Appendixes for Volume 2 (Part 2) of a seven volume Satellite (SPS) report are presented. The document contains two appendixes. The first is a SPS work breakdown structure dictionary. The second gives SPS cost estimating relationships and contains the cost analyses and a description of cost elements that comprise the SPS program. G.Y.

N79-23488*# Rockwell International Corp., Downey, Calif. Satellite Systems Div.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 4: TRANSPORTATION ANALYSIS Final Report
G. M. Hanley Mar. 1979 268 p refs 7 Vol.
(Contract NAS8-32475)
(NASA-CR-161222; SSD-79-0010-4-Vol-4) Avail: NTIS HC A12/MF A01 CSCL 10B

Volume 4 of a seven volume Satellite Power Systems (SPS) is presented. This volume is divided into the following sections: (1) transportation systems elements; (2) transportation systems requirements; (3) heavy lift launch vehicles (HLLV); (4) LEO-GEO transportation; (5) on-orbit mobility systems; (6) personnel transfer systems; and (7) cost and programmatics. Three appedixes are also provided and they include: horizontal takeoff (single stage to orbit technical summary); HLLV reference vehicle trajectory and trade study data; and electric orbital transfer vehicle sizing. G.Y.

N79-23489*# Rockwell International Corp., Downey, Calif. Satellite Systems Div.
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 7: SYSTEM/SUBSYSTEM REQUIREMENTS DATA BOOK Final Report
G. M. Hanley Mar. 1979 118 p refs 7 Vol.
(Contract NAS8-32475)
(NASA-CR-161223; SSD-79-0010-7-Vol-7) Avail: NTIS HC A06/MF A01 CSCL 10B

Volume 7 of the Satellite Power Systems (SPS) Concept Definition Study final report summarizes the basic requirements used as a guide to systems analysis and is a basis for the selection of candidate SPS point design(s). Initially, these collected data reflected the level of definition resulting from the evaluation of a broad spectrum of SPS concepts. As the various concepts matured these requirements were updated to reflect the requirements identified for the projected satellite system/subsystem point design(s). The identified subsystem/systems requirements are defined, and where appropriate, recommendations for alternate approaches which may represent improved design features are presented. A more detailed discussion of the selected point design(s) will be found in Volume 2 of this report. G.Y.

N79-23492*# Kotin (Allan D.) Economic Consultants, Los Angeles, Calif.
SATELLITE POWER SYSTEM (SPS) RESOURCE REQUIREMENTS (CRITICAL MATERIALS, ENERGY AND LAND)
Allan D. Kotin Oct. 1978 126 p refs Sponsored by NASA and DOE Prepared for PRC Energy Analysis Co.
(Contract EG-77-C-01-4024)
(NASA-CR-158680; HCP/R-4024-02) Avail: NTIS HC A07/MF A01 CSCL 10B

The resource impacts of the proposed satellite power system are evaluated. Three classes of resource impacts are considered separately: critical materials, energy, and land use. The analysis focuses on the requirements associated with the annual development of two five-gigawatt satellites and the associated receiving facilities. M.M.M.

N79-23496*# PRC Energy Analysis Co., McLean, Va.
POTENTIAL OF LASER FOR SPS POWER TRANSMISSION
Claud N. Bain Oct. 1978 111 p refs Sponsored by NASA and DOE
(Contract EG-77-C-01-4024)
(NASA-CR-157432; HCP/R-4024-07) Avail: NTIS HC A06/MF A01 CSCL 10B

Research on the feasibility of using a laser subsystem as an additional option for the transmission of the satellite power system (STS) power is presented. Current laser work and predictions for future laser performance provide a level of confidence that the development of a laser power transmission system is technologically feasible in the time frame required to develop the SBS. There are significant economic advantages in lower ground distribution costs and a reduction of more than two orders of magnitude in real estate requirements for ground based receiving/conversion sites. M.M.M.

N79-23499*# PRC Energy Analysis Co., McLean, Va.
SATELLITE POWER SYSTEM (SPS) MAPPING OF EXCLUSION AREAS FOR RECTENNA SITES
James B. Blackburn, Jr. and Bill A. Bavinger Oct. 1978 116 p refs Sponsored by NASA and DOE
(Contract EG-77-C-01-4024)
(NASA-CR-157435; HCP/R-4024-10) Avail: NTIS HC A06/MF A01 CSCL 10B

The areas of the United States that were not available as potential sites for receiving antennas that are an integral part of the Satellite Power System concept are presented. Thirty-six variables with the potential to exclude the rectenna were mapped and coded in a computer. Some of these variables exclude a rectenna from locating within the area of its spatial influence, and other variables potentially exclude the rectenna. These maps of variables were assembled from existing data and were mapped on a grid system. M.M.M.

N79-23500*# PRC Energy Analysis Co., McLean, Va.
SATELLITE POWER SYSTEM (SPS) MILITARY IMPLICATIONS
Claud N. Bain Oct. 1978 49 p refs Sponsored by NASA and DOE

(Contract EG-77-C-01-4024)
(NASA-CR-157436; HCP/R-4024-11) Avail: NTIS
HC A03/MF A01 CSCL 10B

The military implications of the reference satellite power system (SPS) were examined is well as important military related study tasks. Primary areas of investigation were the potential of the SPS as a weapon, for supporting U.S. military preparedness, and for affecting international relations. In addition, the SPS's relative vulnerability to overt military action, terrorist attacks, and sabotage was considered. M.M.M.

N79-23502*# PRC Energy Analysis Co., McLean, Va.
SATELLITE POWER SYSTEM (SPS) FINANCIAL MANAGEMENT SCENARIOS
Herbert E. Kierolff Oct. 1978 65 p refs Sponsored by NASA and DOE
(Contract EG-77-C-01-4024)
(NASA-CR-157438; HCP/R-4024-13) Avail: NTIS
HC A04/MF A01 CSCL 10B

The factors involved in the evaluation of the Satellite Power System's (SPS) feasibility and in SPS financing and management are presented. Areas for further research are also enumerated. M.M.M.

N79-24024*# Parker (Lee W.), Inc., Concord, Mass.
PLASMA SHEATH EFFECTS AND VOLTAGE DISTRIBUTIONS OF LARGE HIGH-POWER SATELLITE SOLAR ARRAYS
Lee W. Parker *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 341-357 refs

Avail: NTIS HC A99/MF A01 CSCL 22B

Knowledge of the floating voltage configuration of a large array in orbit is needed in order to estimate various plasma-interaction effects. The equilibrium configuration of array voltages relative to space depends on the sheath structure. The latter dependence for an exposed array is examined in the light of two finite-sheath effects. One effect is that electron currents may be seriously underestimated. The other is that a potential barrier for electrons can occur, restricting electron currents. A conducting surface is assumed on the basis of a conductivity argument. Finite-sheath effects are investigated. The results of assuming thin-sheath and thick-sheath limits on the floating configuration of a linearly connected array are studied. Sheath thickness and parasitic power leakage are estimated. Numerically computed fields using a 3-D code are displayed in the thick-sheath limit. G.Y.

N79-24026*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
MAGNETIC SHIELDING OF LARGE HIGH-POWER-SATELLITE SOLAR ARRAYS USING INTERNAL CURRENTS
Lee W. Parker (Parker (Lee W.), Inc., Concord, Mass.) and William A. Oran *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 376-387 refs

Avail: NTIS HC A99/MF A01 CSCL 22B

Present concepts for solar power satellites involve dimensions up to tens of kilometers and operating internal currents up to hundreds of kiloamperes. A question addressed is whether the local magnetic fields generated by these strong currents during normal operation can shield the array against impacts by plasma ions and electrons (and from thruster plasmas) which can cause possible losses such as power leakage and surface erosion. One of several prototype concepts was modeled by a long narrow rectangular panel 2 km wide and 20 km long. The currents flow in a parallel across the narrow dimension (sheet current) and along the edge (wire currents). The wire currents accumulate from zero to 100 kiloamp and are the dominant sources. The magnetic field is approximated analytically. The equations of motion for charged particles in this magnetic field are analyzed. The ion and electron fluxes at points on the surface are represented analytically for monoenergetic distributions and are evaluated. G.Y.

N79-24028*# Rice Univ., Houston, Tex. Dept. of Space Physics and Astronomy.
SPACE ENVIRONMENTAL EFFECTS AND THE SOLAR POWER SATELLITE
John W. Freeman, David Cooke, and Patricia Reiff *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 408-418 refs
Avail: NTIS HC A99/MF A01 CSCL 22B

Some preliminary findings regarding the interactions between the space plasma at GEO and the Marshall Space Flight Center January 1978 baseline Satellite Power Systems (SPS) design are summarized. These include the following: (1) the parasitic load will be dominated by photoelectrons and will amount to about 34 MW; (2) material of higher conductivity than kapton should be used for the solar reflector substrate and the solar cell blanket support material; (3) the satellite structure and solar reflector should be tied electrically to midpoint voltage of each solar cell array; and (4) tests should be run on the proposed solar cell cover glass material (synthetic sapphire) to determine if breakdown is expected. G.Y.

N79-24436*# National Aeronautics and Space Administration, Washington, D. C.
PRELIMINARY ENVIRONMENTAL ASSESSMENT FOR THE SATELLITE POWER SYSTEM (SPS). VOLUME 2: DETAILED ASSESSMENT
Oct. 1978 175 p refs Prepared in cooperation with DOE, Washington, D. C. 2 Vol.
(NASA-TM-80355; DOE/ER-0021/2) Avail: NTIS
HC A08/MF A01 CSCL 10B

Volume 2 provides a preliminary assessment of the impact of the Satellite Power System (SPS) on the environment in a technically detailed format more suitable for peer review than the executive summary of Vol. 1. It serves to integrate and assimilate information that has appeared in documents referenced herein and to focus on issues that are purely environmental. It discloses the state-of-knowledge as perceived from recently completed DOE-sponsored studies and defines prospective research and study programs that can advance the state-of-knowledge and provide an expanded data base for use in an assessment planned for 1980. Alternatives for research that may be implemented in order to achieve this advancement are also discussed. Author

N79-28213# Aerospace Corp., El Segundo, Calif. Space Sciences Lab.
ENVIRONMENTAL FACTORS OF POWER SATELLITES Interim Report
Yam T. Chiu and Barbara K. Ching 6 Jul. 1979 49 p refs
(Contract F04701-78-C-0079)
(SAMSO-TR-79-66; TR-0079(4960-04)-5) Avail: NTIS
HC A03/MF A01

All presently known factors in the construction and operation of the proposed solar power satellite which may produce effects on the environment from ground level to beyond the magnetopause are reviewed. Characteristics of the propulsion system exhausts of the space segment, the microwave beam, the satellite physical structure, and the HLLV launch and landing activities are described. A.R.H.

N79-29212# Committee on Science and Technology (U. S. House).
SOLAR POWER SATELLITE
Washington GPO 1979 344 p refs Hearings before the Subcomm. on Space Sci. and Applications of the Comm. on Sci. and Technol., 96th Congr., 1st Sess., 28-30 Mar. 1979
(GPO-45-997) Avail: Subcomm. on Space Sci. and Applications

A technology verification program to enable the resolution of the technical, environmental, and economic issues surrounding the concept of a solar power satellite is considered. Specific issues discussed include: biological and ionospheric impacts; radio frequency interference; and research on the space segment of the microwave power system to ensure technical and economic feasibility. J.M.S.

N79-30726 Committee on Energy and Natural Resources (U. S. Senate).
SOLAR POWER SATELLITE RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM ACT OF 1978
Washington GPO 1978 270 p refs Hearing on S. 2860 and H.R. 12505 before the Subcomm. on Energy and Natural Resources, 95th Congr., 2d Sess., 14 Aug. 1978
(GPO-35-994; Publ-95-166) Avail: Subcomm. on Energy Res. and Development

Satellite solar énergy conversion transmission to earth to generate electricity for domestic purposes is studied. A space orbiting mirror system designed to provide continuous and slightly concentrated reflected solar energy to selected solar conversion sites is examined. Development of this system is discussed through economic viability, design feasibility, and energy storage and conversion techniques. A.W.H.

N79-30730# European Space Agency, Paris (France).
PHOTOVOLTAIC GENERATORS IN SPACE
K. Bogus, ed and T. D. Guyenne, ed Nov. 1978 344 p refs Proc. of 1st European Symp. on Photovoltaic Generators in Space, Noordwijk, Neth., 11-13 Sep. 1978
(SP-140) Avail: NTIS HC A15/MF A01

A series of lectures was given including, as main topics, solar cell technology, module and blanket technology, design analysis and verification, interface problems, evolution of photovoltaics, solar power satellites, solar arrays, and test results as well as flight data.

N79-30750*# Boeing Aerospace Co., Seattle, Wash.
SOLAR POWER SATELLITES: THE ENGINEERING CHALLENGES
G. R. Woodcock *In* ESA Photovoltaic Generators in Space Nov. 1978 p 139-147

(Contract NAS9-15196)
Avail: NTIS HC A15/MF A01

Certain elements of solar power satellite design and system engineering studies are reviewed analyzing solar power satellites as a potential baseload electric power source. The complete system concept concept includes not only the satellites and their ground stations, but also the space transportation for delivery of the satellites, piece by piece, into space, and the factories for their construction in space. Issues related to carrying the solar power satellite concept from the present design study phase through implementation of actual hardware are considered. The first issue category is environmental aspects of the SPS systems. The second category of issues is the technology risks associated with achieving the necessary component and subsystem performances. The third category includes the engineering issues associated with carrying out such a large scale project. The fourth issue category is financial: the funding required to bring such a project into being and the costs of the satellites and resulting cost of the power produced as compared to potential alternative energy sources. Author (ESA)

N79-30751# European Space Agency, Noordwikj (Netherlands).
INTERFACE PROBLEMS ON AN SPS SOLAR ARRAY BLANKET
D. Kassing *In* ESA Photovoltaic Generators in Space Nov. 1978 p 149-159 refs

Avail: NTIS HC A15/MF A01

Starting from a survey of proposed photovoltaic Solar Power Satellite (SPS) configurations, the design trend of solar arrays applicable in an SPS development program is sketched out indicating physical and other interface problems of the solar array sub-system with adjacent sub-system and the space environment. The nature of research and development program on SPS solar cell blankets is descussed and a list containing potential study tasks for the near future is presented. The objective is to identify, from a systems engineering of view, the limiting conditions and interface problems associated with the development and operation of large solar generator blankets to be used in SPS systems and to discuss the nature of the supporting research and technology program aimed at solving the mentioned interface problems. Author (ESA)

N79-30752# Technische Univ., Berlin (West Germany). Inst. fuer Luft und Raumfahrt.
MOSGEN: A POTENTIAL EUROPEAN CONTRIBUTION IN DEVELOPING LARGE SOLAR GENERATORS SUITABLE FOR GROWING POWER LEVELS UP TO SPS-SYSTEMS
J. Ruth and W. Westphal *In* ESA Photovoltaic Generators in Space Nov. 1978 p 161-166 refs

Avail: NTIS HC A15/MF A01

A potential development program for large solar generators in space, which seems to be suited especially for European needs is discussed. The cost of production and transport have to be reduced to a minimum by constructive and technological steps so that they become competitive power plants. The concept or a modular collector system represents one steps in that direction. The modular philosophy is easily transferable to different sizes and applications of solar generators leading to solar power satellites. An evolutionary strategy of development helps to provide high economical benefit of the modular attempt compared to nonmodular separately developed alternatives. This strategy means governing the development process by feed back dynamic optimization. Author (ESA)

N79-31251*# PRC Energy Analysis Co., McLean, Va.
SATELLITE POWER SYSTEM (SPS) RESOURCE REQUIREMENTS (CRITICAL MATERIALS, ENERGY, AND LAND)
Allan D. Kotin (Kotin (Allan D.) Economic Consultants, Los Angeles, Calif.) Oct. 1978 126 p refs Sponsored in cooperation with NASA
(Contract EG-77-C-01-4024)
(NASA-CR-162310; SE-4024-T1) Avail: NTIS HC A07/MF A01 CSCL 10A

The resource impacts of the proposed satellite power system (SPS) were reviewed. Three classes of resource impacts were considered separately: critical materials, energy and land use. The analysis focused on the requirements associated with the annual development of two five-gigawatt satellites and the associated receiving facilities. DOE

N79-31764*# Chicago Univ., Ill. Enrico Fermi Inst.
WINSTON SOLAR CONCENTRATORS AND EVALUATION SUPPORT. PHASE 2: NON-IMAGING CONCENTRATORS FOR SPACE APPLICATIONS Final Report, Oct. 1977 - Jul. 1978
Roland Winston, Joseph OGallagher, and Peretz Greenman 28 Aug. 1978 81 p refs Prepared for JPL
(Contract JPL-954563)
(NASA-CR-162279) Avail: NTIS HC A05/MF A01 CSCL 10A

A 4.67X, plus or minus 5 deg. compound parabolic concentrator (CPC) for a large photovoltaic array in space was analyzed. The design was demonstrated to be effective in achieving a net power gain which can be varied from more than a factor of 3 down to approximately unity. A method for reducing nonuniformities in illumination to a given desired level was found. The effectiveness of this method, which involves the introduction of a degree of non-specularity in the reflector surface, was confirmed

by direct measurements with prepared foil reflectors in a CPC in terrestrial sunshine as well as by computer ray tracing. Further ray tracing confirms that the CPC design is extremely tolerant to pointing and alignment errors, minor distortions, etc. A two stage non-imaging design was shown, by preliminary measurements and analysis, to provide both the desired angular tolerance and the required degree of intensity uniformity if higher concentrations (4X-10X) are necessary. Author

N79-32641*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
THE NASA LEWIS RESEARCH CENTER PROGRAM IN SPACE SOLAR CELL RESEARCH AND TECHNOLOGY
Henry W. Brandhorst, Jr. *In its* Solar Cell High Efficiency and Radiation Damage, 1979 Aug. 1979 p 1-4

Avail: NTIS HC A13/MF A01 CSCL 10A

Progress in space solar cell research and technology is reported. An 18 percent-AMO-efficient silicon solar cell, reduction in the radiation damage suffered by silicon solar cells in space, and high efficiency wrap-around contact and thin (50 micrometer) coplanar back contact silicon cells are among the topics discussed. Reduction in the cost of silicon cells for space use, cost effective GaAs solar cells, the feasibility of 30 percent AMO solar energy conversion, and reliable encapsulants for space blankets are also considered. J.M.S.

N79-32642*# Air Force Aero Propulsion Lab., Wright-Patterson AFB, Ohio.
SOLAR PHOTOVOLTAIC RESEARCH AND DEVELOPMENT PROGRAM OF THE AIR FORCE AERO PROPULSION LABORATORY
Joseph Wise *In* NASA. Lewis Res. Center Solar Cell High Efficiency and Radiation Damage, 1979 Aug. 1979 p 5-8

Avail: NTIS HC A13/MF A01 CSCL 10A

Progress is reported in the following areas: laser weapon effects, solar silicon solar cell concepts, and high voltage hardened, high power system technology. Emphasis is placed on solar cells with increased energy conversion efficiency and radiation resistance characteristics for application to satellite power systems. J.M.S.

N79-32643*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
THE JPL SPACE PHOTOVOLTAIC PROGRAM
John A. Scott-Monck *In* NASA. Lewis Res. Center Solar Cell High Efficiency and Radiation Damage, 1979 Aug 1979 p 9-12
(Contract NAS7-100)
Avail: NTIS HC A13/MF A01 CSCL 10A

The development of energy efficient solar cells for space applications is discussed. The electrical performance of solar cells as a function of temperature and solar intensity and the influence of radiation and subsequent thermal annealing on the electrical behavior of cells are among the factors studied. Progress in GaAs solar cell development is reported with emphasis on improvement of output power and radiation resistance to demonstrate a solar cell array to meet the specific power and stability requirements of solar power satellites. J.M.S.

11
GENERAL

Includes either state-of-the-art or advanced technology which may apply to Large Space Systems and does not fit within the previous nine categories. Shuttle payload requirements, on-board requirements, data rates, and shuttle interfaces, and publications of conferences, seminars, and workshops will be covered in this area.

A79-24000 **The dimensioning of complex steel members in the range of endurance strength and fatigue life (Dimensionierung komplizierter Bauteile aus Stahl im Bereich der Zeit- und Dauerfestigkeit).** O. R. Lang (Daimler-Benz AG, Stuttgart, West Germany). *Zeitschrift für Werkstofftechnik,* vol. 10, Jan. 1979, p. 24-29. 27 refs. In German.

The considered dimensioning concept makes a distinction between actual and admissible stresses. The concept was developed on the basis of an evaluation of approximately 1600 individual measurements reported in various publications. The requirements regarding a practical implementation of the dimensioning concept are taken into account by basing the procedure on the static strength data which are already known in the design stage. Attention is given to a regression formula for the determination of the long-term alternating-strength stress for unnotched specimens, the long-term alternating-strength stress of notched members, aspects of medium-stress dependence, the effect of boundary layer strengthening, endurance strength, and application examples, including a gear-wheel, and a crankshaft. G.R.

A79-24021 **Anomalous intensity ratios of the resonance to intercombination lines of He-like ions in Nd- and CO2-laser-produced plasma.** V. A. Boiko, A. Iu. Chugunov, A. Ia. Faenov, S. A. Pikuz, I. Iu. Skobelev, A. V. Vinogradov, and E. A. Iukov (Akademiia Nauk SSSR, Fizicheskii Institut, Moscow, USSR). *Journal of Physics B - Atomic and Molecular Physics,* vol. 12, Jan. 28, 1979, p. 213-220. 25 refs.

Anomalously small values of the intensity ratio alpha of resonance and intercombination lines of He-like ions have been observed in Nd- and CO2-laser-produced plasmas. The values of alpha obtained are explained via calculations using a non-stationary ionization model for the plasma (overheated, for CO2-laser plasma, and supercooled, for expanding Nd-laser plasma). The measurements of the intensity ratio may be used to obtain information on the relative concentrations of H-, He-, and Li-like ions in the plasma. The results obtained allow one to answer the questions: when must the non-stationary character of the plasma ionization state be taken into account for the observed spectra to be interpreted correctly and when can one use more simple stationary models for the plasma concerned. (Author)

A79-30782 # **A method of controlling orbits of geostationary satellites with minimum fuel consumption.** K. Takahashi. *Radio Research Laboratories, Journal,* vol. 25, July-Nov. 1978, p. 247-259.

The orbital angular velocity of a stationary satellite is considered to express the perturbation on an orbit of the satellite, and to draw the conclusion that the minimum variation in direction of this velocity agrees with the minimum fuel consumption to maintain a stationary satellite within allocated bounds. The directional variation of the orbital angular velocity is kept minimum by maintaining the ascending node of the orbit in about the direction of the vernal equinox. The direction of the ascending node with minimum fuel consumption to maintain the orbit is given over 18.6 year nodal period of the moon, over which period the inclination variation of the orbit and the angular speed proportional to the necessary amount of fuel to maintain the orbit are also given. The method in this paper is applicable to geostationary communication satellites, UHF broadcasting satellites, solar power satellites etc. (Author)

A79-33992 * **SOLARES - A new hope for solar energy.** K. W. Billman, W. P. Gilbreath (NASA, Ames Research Center, Moffett Field, Calif.), and S. W. Bowen. In: Alternative energy sources; Proceedings of the Miami International Conference, Miami Beach, Fla., December 5-7, 1977. Volume 1. Washington, D.C., Hemisphere Publishing Corp., 1978, p. 233-255. 13 refs.

A system of orbiting reflectors, SOLARES, has been studied as a possible means of reducing the diurnal variation and enhancing the average intensity of sunlight with a space system of minimum mass and complexity. The key impact that such a system makes on the economic viability of solar farming and other solar applications is demonstrated. The system is compatible with incremental implementation and continual expansion to meet the world's power needs. Key technology, environmental, and economic issues and payoffs are identified. SOLARES appears to be economically superior to other advanced, and even competitive with conventional, energy systems and could be scaled to completely abate our fossil fuel usage for power generation. Development of the terrestrial solar conversion technique, optimized for this new artificial source of solar radiation, yet remains. (Author)

A79-34701 * **Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers.** Conference sponsored by the American Institute of Aeronautics and Astronautics and NASA. New York, American Institute of Aeronautics and Astronautics, Inc., 1979. 605 p. Members, $60.; nonmembers, $70.

Propulsion systems for spacecraft, satellite communications technology, the design of large light-weight erectable structures for assembly in space, electronics and information processing for spacecraft, and self-diagnostic, fault-tolerant controls based on high memory and processing capabilities are discussed. Topics of the papers include the design of large delta wings for earth-to-orbit transports, dual-fuel propulsion units, magnetoplasmadynamic thrusters, heating rates on blunt-nosed bodies at various angles of attack, remote manipulators for space assembly tasks, solar electric propulsion for planetary missions, deployable space platforms with multiple payloads, the design of large offset-fed antennas, a nonlinear stress-strain relationship for metallic meshes, and adaptive sensors for spacecraft. J.M.B.

A79-34705 * # **A space-based orbital transfer vehicle - Bridge to the future.** J. J. Rehder and D. G. Eide (NASA, Langley Research Center, Vehicle Analysis Branch, Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 30-38. 8 refs. (AIAA 79-0865)

A comparison is made between a space-based and earth-based orbital transfer vehicle (OTV) for use in the Shuttle era and beyond. The space-based vehicle alleviates the limited capability inherent in an earth-based OTV whose design is constrained by a particular launch vehicle. Several sizes of space-based OTVs were generated and compared with an earth-based system for a number of mission scenarios with varying types and levels of traffic. The space-based OTVs showed substantial cost savings for each scenario, with the smallest space-based vehicle showing the largest saving. The space-based OTV retains the cost advantage even if the number of missions or the Shuttle cost-per-flight is drastically reduced. (Author)

A79-34728 * # Preliminary design for a space based orbital transfer vehicle. I. O. MacConochie, J. J. Rehder (NASA, Langley Research Center, Space Systems Div., Hampton, Va.), and E. P. Brien (Kentron International, Inc., Hampton, Va.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 220-224. 7 refs. (AIAA 79-0897)

A space-based orbital transfer vehicle has been sized for a 50-metric-ton payload delivery from low-earth-orbit to a geosynchronous orbit. Space basing effected substantial reductions in cryogenic insulation, tank, and body structure. The tank and body structural masses are shown to be lower for space basing because of the larger difference in acceleration loads between the on-orbit case (0.2 g's) and delivery (3.0 g's), the latter applying to ground-based vehicles which are delivered to orbit fully loaded with propellants. Insulation masses are lower because of the absence of an atmosphere and the attendant heat transfer losses. Insulation systems masses are also reduced because of the elimination of the problem of liquefaction and freezing of moisture on the tanks. (Author)

A79-34739 * # Synchronous orbit power technology needs. L. W. Slifer, Jr. (NASA, Goddard Space Flight Center, Power Applications Branch, Greenbelt, Md.) and W. J. Billerbeck (COMSAT Laboratories, Clarksburg, Md.). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979, p. 315-323. 16 refs. Research supported by COMSAT Laboratories and NASA. (AIAA 79-0916)

An attempt is made to define the needs for future geosynchronous spacecraft power subsystem components, including power generation, energy storage, and power processing. Three projected models (a mission model, an orbit transfer vehicle model, and a mass model) for power subsystem components are used to define power requirements and mass limitations for future spacecraft. Based upon these models, the power subsystems for a 10-kW, 10-year-life, dedicated spacecraft and for a 20-kW, 20-year-life multimission platform are analyzed to establish power density requirements for orbit transfer vehicles. Comparison of these requirements to state-of-the-art (Intelsat 5) design values shows that major improvements, by a factor of 2 or more, are needed to accomplish the near term missions. B.J.

A79-34775 * # Large space system - Charged particle environment interaction technology. N. J. Stevens, J. C. Roche, and N. T. Grier (NASA, Lewis Research Center, Cleveland, Ohio). In: Conference on Advanced Technology for Future Space Systems, Hampton, Va., May 8-10, 1979, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1979. 21 p. 31 refs. (AIAA 79-0913)

Large high-voltage space power systems proposed for future applications in both low earth orbit and geosynchronous altitudes must operate in the space charged-particle environment with possible interactions between this environment and the high-voltage surfaces. The paper reviews the ground experimental work to provide indicators for the interactions that could exist in the space power system. A preliminary analytical model of a large space power system is constructed using the existing NASA Charging Analyzer Program, and its performance in geosynchronous orbit is evaluated. The analytical results are used to illustrate the regions where detrimental interactions could exist and to establish areas where future technology is required. S.D.

A79-34860 * The future United States space program; Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978. Parts 1 & 2. Conference sponsored by the American Astronautical Society, Boeing Co., General Electric Co., IBM Corp., Lockheed Electronics Co., Northrop Services, Inc., Technology, Inc., and NASA. Edited by R. S. Johnston (NASA, Johnson Space Center, Houston, Tex.), A. Naumann, Jr. (Lockheed Electronics Co., Inc., Plainfield, N.J.), and C. W. G. Fulcher (General Electric Co., Fairfield, Conn.). San Diego, Calif., American Astronautical Society (Advances in the Astronautical Sciences, Volume 38, Pts. 1 & 2); Univelt, Inc., 1979. Pt. 1, 442 p; pt. 2, 432 p. Price of two parts, $80.

Space Shuttle guidance problems, solar power satellites, space law, satellite communications, space medicine, and engineering of large space systems are discussed. Topics of the papers include biological experiments designed for the Space Shuttle, an optimized guidance law for Space Shuttle re-entry, aircraft propulsion based on laser energy, industrial materials available in the lunar soil, health programs for a solar power satellite construction team, closed life support systems for large habitats in space, the advantages of a manned mission to Mars, the interpretation of radar imagery of Venus, a cost analysis for the satellite power system, and the geological history of Mars. J.M.B.

A79-34865 Future programs in space. J. A. Snow (U.S. Department of Energy, Office of Energy Research, Washington, D.C.). In: The future United States space program; Proceedings of the Twenty-fifth Anniversary Conference, Houston, Tex., October 30-November 2, 1978. Part 2. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1979, p. 689-703. (AAS 78-180)

There are a variety of areas in which space has the potential for contributing to the future well-being of the United States and the world. It has been evident - even before the current intense focus on energy problems - that remote sensing from aircraft and spacecraft can make significant contributions to energy, as related to exploration, extraction, power plant siting, environmental monitoring and assessment, and applications for developing nations. A discussion of requirements for implementation of satellite power systems reveals that there is a potential future for a vastly abundant supply of energy through the satellite power system. The U.S. civil space policy is also examined. S.D.

A79-38060 # Externally pumped Rankine cycle thermal transport devices. R. J. Hannemann (Digital Equipment Corp., Maynard, Mass.). *American Institute of Aeronautics and Astronautics, Thermophysics Conference, 14th, Orlando, Fla., June 4-6, 1979, Paper 79-1091.* 7 p. 10 refs.

An attempt is made to document a brief feasibility study of the use of externally pumped heat pipes (EPHPs) for the thermal control of large structures in space. The discussion is limited to a simplified EPHP analysis, idealized performance for space structure isothermalization, and potential terrestrial applications. If the source and sink have finite thermal capacities, the EPHP will tend to equalize their temperatures, which is the desired goal for eliminating thermal stresses in large structures. The EPHP offers significantly improved thermal performance if one is willing to pay the price of supplying a small amount of pumping power. Terrestrial uses, such as thermal transport in solar energy systems or electronic equipment cooling, are potentially even more significant than space application. S.D.

A79-44248 * Planning Space Shuttle's maiden voyage. M. S. Malkin and R. F. Freitag (NASA, Washington, D.C.). *IEEE Spectrum,* vol. 16, July 1979, p. 42-50.

NASA's first Space Shuttle, Columbia, whose technological advances include a space laboratory, navigational and communication satellites, and planetary explorers, is examined, and the first few flights, scheduled for 1980, are described. The Shuttle employs an

all-digital, all-electronic, computer-operated avionics system. The onboard data processing and software subsystem, encompassing five computers (four online and one backup), a data-bus network, bus terminals, and software, is analyzed in detail. Attention is given to the basic structure of the Orbiter (37.19 m in length and 23.77 m wingspan), its main engines, and the payload and cargo capacities (29,500 kg). A two-step program that could increase the power and duration of spaceflights is presented. The first step is the creation of a power extension package, using solar arrays, generating electricity to extend the basic five-day flight to 20 days, while the second step uses the same design to create a 25-kW power model capable of providing energy for a 50-day flight. Plans for construction of a manned space construction base and a larger power platform of 250 kW are also presented. C.F.W.

A79-53255 * **Orbit transfer operations for the Space Shuttle era.** H. P. Davis (NASA, Johnson Space Center, Houston, Tex.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-29.* 20 p. 15 refs.

Orbit transfer operations are reviewed relative to the objectives, operational factors, and crew model concepts of future mission requirements. The review is based on studies presently underway and on projected needs and goals of the Space Shuttle era. Numerous tradeoff studies and further analyses are needed before the best form of the manned geostationary vehicle becomes fixed. However, the Shuttle can provide the necessary low-orbit logistics service for dispatching manned geostationary missions on as frequent a schedule as will be needed to serve the advanced geostationary satellites of the near future. S.D.

A79-53256 **Orbit transfer needs of the late 1980s and the 1990s.** M. G. Wolfe and R. A. Hartunian (Aerospace Corp., El Segundo, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-30.* 15 p. 22 refs.

This paper presents future orbit transfer requirements and examples of advanced revolutionary spacecraft. Early high-energy payloads will be transferred from Shuttle orbit to higher orbit with the expendable IUS or the Spinning Solid Upper Stage. Later the advanced payloads will require a more sophisticated Orbit Transfer Vehicle (OTV) with higher payload capability and orbital operational flexibility. Orbit transfer requirements will extend from synchronous equatorial to planetary orbits, and the advanced spacecraft will be transferred from Shuttle orbit to high earth orbit in the form of separate modules. In addition to transferring primary mission payloads, the OTV will perform many support functions, such as rendezvous and docking, orbital maneuvering, servicing, and the transfer of man. Support facilities, such as power modules and space assembly construction facilities may become candidate OTV payloads, and the additional requirements imposed on the OTV are considered along with those imposed by the primary missions. A.T.

A79-53356 **Space to benefit mankind - 1980 to 2000.** C. L. Gould (Rockwell International Corp., Satellite Systems Div., Downey, Calif.). *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-206.* 22 p. 13 refs.

This paper deals with the use of space for major, tangible benefits with commercial and social value over the next three decades. A background of future needs and trends is presented, and opportunities for applying space to these needs are listed. An overall suggested space industrialization program is presented, and the benefits of such a program are shown. (Author)

A79-53454 # **Space telecommunications at present and in future.** J. Busak. *International Astronautical Federation, International Astronautical Congress, 30th, Munich, West Germany, Sept. 17-22, 1979, Paper 79-IISL-04.* 8 p.

The paper presents information on space telecommunications, which includes a brief summary of the development of the last twenty years, as well as some of the principles on which the Space Treaty of 1967 is based. Attention is given to the agenda of the World Administrative Radio Conference, to be held in latter part of 1979. Topics that will be discussed are examined, including geostationary satellite orbit, broadcasting-satellite service, telecommunication satellite systems, earth exploration satellites, solar power satellites, and the search for extraterrestrial intelligence. C.F.W.

N79-22188*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
LARGE SPACE SYSTEM: CHARGED PARTICLE ENVIRONMENT INTERACTION TECHNOLOGY
N. John Stevens, James C. Roche, and Normant T. Grier 1979 23 p refs Presented at the Conf. on Advanced Technol. for Future Space Systems, Hampton, Va., 8-11 May 1979; sponsored by AIAA
(NASA-TM-79156; E-012) Avail: NTIS HC A02/MF A01 CSCL 22B

Large, high voltage space power systems are proposed for future space missions. These systems must operate in the charged-particle environment of space and interactions between this environment and the high voltage surfaces are possible. Ground simulation testing indicated that dielectric surfaces that usually surround biased conductors can influence these interactions. For positive voltages greater than 100 volts, it has been found that the dielectrics contribute to the current collection area. For negative voltages greater than-500 volts, the data indicates that the dielectrics contribute to discharges. A large, high-voltage power system operating in geosynchronous orbit was analyzed. Results of this analysis indicate that very strong electric fields exist in these power systems. S.E.S.

N79-22539*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
THE 13TH AEROSPACE MECHANISMS SYMPOSIUM
Aleck C. Bond 1979 300 p refs Proc. of Symp. held at Houston, Tex., 26-27 Apr. 1979
(NASA-CP-2081; S-496) Avail: NTIS HC A13/MF A01 CSCL 13I

Technological areas covered include propulsion, motion compensation, instrument pointing and adjustment, centrifuge testing, bearing design, vehicle braking, and cargo handling. Devices for satellite, missile, and hypersonic-wind-tunnel applications; space shuttle mechanical and thermal protection systems; and techniques for building large space structures are described. In addition, a fluid drop injector device for a Spacelab experiment, a helical grip for cable cars, and applications of rare earth permanent magnets are discussed.

N79-23666*# Hamilton Standard, Hartford, Conn.
CONCEPT DEFINITION FOR AN EXTENDED DURATION ORBITER ECLSS
H. Brose Sep. 1977 244 p
(Contract NAS9-14782)
(NASA-CR-160164) Avail: NTIS HC A11/MF A01 CSCL 06K

Extending the seven-day Shuttle Orbiter baseline mission requires an evaluation of the Environmental Control and Life Support (ECLS) System in order to determine those changes necessary or desirable so that the Orbiter payload capability will not be seriously compromised. The ECLSS requirements and subsystem options for extended duration Orbiter missions are defined. Each major ECLS subsystem was examined, and potential methods of extending the mission capability were studied. The mission evaluated most extensively for this effort was a 30 day mission with a crew size of seven men. However, missions up to 90 days duration with crew sizes of three to ten men were also examined. G.Y.

N79-24001*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
SPACECRAFT CHARGING TECHNOLOGY, 1978
1979 908 p refs Conf. held at Colorado Springs, Colo., 31 Oct. - 2 Nov. 1978; sponsored by NASA and AFGL
(NASA-CP-2071; AFGL-TR-79-0082) Avail: NTIS HC A99/MF A01 CSCL 22B

The interaction of the aerospace environment with spacecraft surfaces and onboard, high voltage spacecraft systems operating over a wide range of altitudes from low Earth orbit to geosynchronous orbit is considered. Emphasis is placed on control of spacecraft electric potential. Electron and ion beams, plasma neutralizers material selection, and magnetic shielding are among the topics discussed.

N79-24019*# Air Force Geophysics Lab., Hanscom AFB, Mass.
THE CALCULATION OF SPACECRAFT POTENTIAL: COMPARISON BETWEEN THEORY AND OBSERVATION
H. B. Garrett *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 239-255 refs

Avail: NTIS HC A99/MF A01 CSCL 22B

A simple charge balance model based on the work of DeForest was adapted for the calculation of spacecraft potentials. The model was calibrated with ATS 5 plasma data. Once calibrated, the model was used to calculate the time-varying potential that was observed as a spacecraft passes in and out of eclipse. Errors on the order of + or - 800 volts were observed over a range of 0 to -10,000 volts. Possible applications of the model to large space structures are discussed. J.A.M.

N79-24054*# Spire Corp., Bedford, Mass.
A COMBINED SPACECRAFT CHARGING AND PULSED X-RAY SIMULATION FACILITY
Steven H. Face, Michael J. Nowlan, William R. Neal, and William A. Seidler *In* NASA. Lewis Res. Center Spacecraft Charging Technol., 1978 1979 p 854-867 refs Sponsored by DNA

Avail: NTIS HC A99/MF A01 CSCL 22B

A spacecraft charging simulation facility constructed to investigate the response of satellite materials in a typical geomagnetic substorm environment is described. The conditions simulated include vacuum, solar radiation, and substorm electrons. A nuclear threat environment simulation using a flash X ray generator is combined with the spacecraft charging facility. Results obtained on a solar cell array segment used for a preliminary facility demonstration are presented with a description of the facility. M.M.M.

N79-25927# Committee on Commerce, Science, and Transportation (U. S. Senate).
NASA AUTHORIZATION FOR FISCAL YEAR 1980, PART 2
Washington GPO 1979 507 p refs Hearings on S. 357 before the Comm. on Commerce, Sci., and Transportation, 96th Congr., 1st Sess., 21-22 and 28 Feb. 1979
(GPO-43-135) Avail: Comm. on Commerce, Sci., and Transportation

Testimony delivered and statements received to justify NASA's budget requests to support program management, research and development, construction of facilities, and other activities are presented. Implications of the civilian space policy, capabilities of the space shuttle, and the status of its main engine are discussed as well as accomplishments in advanced programs related to power systems, space platforms and space transportation systems, and satellite services. A.R.H.

N79-30093# Committee on Commerce, Science, and Transportation (U. S. Senate).
NASA AUTHORIZATION FOR FISCAL YEAR 1980, PART 3
Washington GPO 1979 558 p refs Hearings on S. 357 before the Comm. on Commerce, Sci., and Transportation, 96th Congr., 1st Sess., 2, 14-15 Mar.; 1 May and 4 Jun. 1979
(GPO-44-885) Avail: Comm. on Commerce, Sci., and Transportation

Testimonies, primarily from NASA (National Aeronautics and Space Administration) witnesses, before the Committee on Commerce, Science, and Transportation (United States Senate) are documented. The hearing was held to authorize appropriations to NASA for research and development, construction of facilities, research and program management, and for other purposes for FY-80. G.Y.

N79-30267*# Rockwell International Corp., Downey, Calif. Satellite Systems Div.
SPACE CONSTRUCTION SYSTEMS ANALYSIS STUDY. TASK 3: CONSTRUCTION SYSTEM SHUTTLE INTEGRATION Final Report
Jun. 1979 28 p
(Contract NAS9-15718)
(NASA-CR-160296) Avail: NTIS HC A03/MF A01 CSCL 22A

The implications and impacts devolving upon the orbiter by its utilization as a space construction facility for the selected flight system projects are presented. G.Y.

N79-30754# Spar Aerospace Products Ltd., Toronto (Ontario).
CANADIAN DEVELOPMENT OF LARGE DEPLOYABLE SOLAR ARRAYS FOR COMMUNICATIONS SPACECRAFT
E. Quittner, H. Borduas, J. T. Renshall, and S. Ahmed (Dept. of Comm., Canada) *In* ESA Photovoltaic Generators in Space Nov. 1978 p 181-192 refs Sponsored by Canadian Dept. of Comm.
Avail: NTIS HC A15/MF A01

Solar array designs that have the potential of cost-effectively satisfying three-axis stabilized geostationary communications satellite power requirements at beginning of life are discussed. The BI-STEM and Astromast deployed 5 and 10 kW beginning of life array designs are examined. To a varying degree the designs were derived from the flight proven Hermes (CTS) array. Except for the Hermes array, all the array designs have the hybrid capability of re-using the spin-phase array segment cells during on-station operation. These arrays were configured to be used on typical spacecraft compatible with both the Ariane and Space Shuttle launchers. Author (ESA)

N79-31084# Committee on Science and Technology (U. S. House).
NASA AUTHORIZATION, 1980, VOLUME 1, PART 3
Washington GPO 1979 610 p refs Hearings on H.R. 1786 before the Subcomm. on Space Sci. and Applications of the Comm. on Sci. and Technol., 96th Congr., 1st Sess., 9-14 Feb. 1979
(GPO-46-422) Avail: Subcomm. on Space Sci. and Applications

Testimony received from personnel at the Kennedy, Johnson, and Marshall Centers as well as at the National Space Technology Laboratories and the Michoud 'facility' is presented. The President's budget plan for the Office of Space Science is discussed with implications for life sciences, planetary explorations, and physics and astronomy programs. Cooperative ventures with the European Space Agency are reviewed. A.R.H.

N79-31085# Committee on Science and Technology (U. S. House).
NASA AUTHORIZATION, 1980, VOLUME 1, PART 4
Washington GPO 1979 760 p refs Hearings on H.R. 1756 before the Subcomm. on Space Sci. and Applications of the Comm. on Sci. and Technol., 96th Congr., 1st Sess., 15, 21-22, 28 Feb., 9, 12 Mar. 1979
(GPO-46-423) Avail: Subcomm. on Space Sci. and Applications

Budget requests for NASA's Office of Space Transportation are justified with emphasis on the supplemental request for space shuttle appropriations. Space applications programs related to using space as a relay point, for Earth observation, and to exploit its specific characteristics are dicussed as well as the satellite conversion and transmission of energy to Earth. Field hearings at Rockwell International and Lockheed are included. A.R.H.

N79-31270# Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany).

ORBITAL TEST SATELLITE (OTS) THERMAL DESIGN AND IN-ORBIT PERFORMANCE

D. Stuempel *In* ESA Spacecraft Thermal and Environ. Control Systems Oct. 1978 p 27-34 refs

Avail: NTIS HC A99/MF A01

The major constraints put on the OTS thermal subsystem are reviewed and the essential steps of the development and test phases along with the final thermal layout summarized. Some emphasis is put on critical problems, their resolution and the consequences for follow-on projects. The subsystem in-orbit performance is briefly demonstrated and discussed vis a vis relevant American achievements. Author (ESA)

N79-31271# European Space Research and Technology Center, Noordwijk (Netherlands).

ORBITAL ASSESSMENT OF OTS THERMAL PERFORMANCE

J.-P. Bouchez, D. H. Howle, and D. Stuempel (Erno Raumfahrttech.) *In* ESA Spacecraft Thermal and Environ. Control Systems Oct. 1978 p 35-45 refs

Avail: NTIS HC A99/MF A01

Thermally, the Orbital Test Program tasks are to evaluate the performance of the thermal control subsystem at regular intervals during satellite lifetime, to assess any degradation with time of the thermal coatings employed, and to assess the accuracy and adequacy of the mathematical thermal model. Subsidiary goals include assessment of the thermal distortion on the large dish antenna performance. The performance of the thermal sub-system to date is briefly assessed, and in-orbit temperatures obtained at the first solstice and first equinox conditions are compared with the corresponding predictions. The differences between flight and predicted temperatures are demonstrated graphically using histograms. Author (ESA)

N79-31306# Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany).

THE OTS HYDRAZINE REACTION CONTROL SYSTEM THERMAL CONDITIONING TECHNIQUE

D. Stuempel *In* ESA Spacecraft Thermal and Environ. Control Systems Oct. 1978 p 375-382 refs

Avail: NTIS HC A99/MF A01

Late development of OTS reaction control subsystems (RCS) thermal control is described. The final concept uses eight telecommand switches, provides separate heater operation for the redundant RCS branches, needs heater power only during sunlight periods of the mission, and maintains the temperatures of all components safely above the freezing point during all mission phases, including the critical transfer orbit and eclipse periods, without reaching unacceptable high temperatures under warm conditions. Experimental flight data show that the system performs within specifications. Author (ESA)

SUBJECT INDEX

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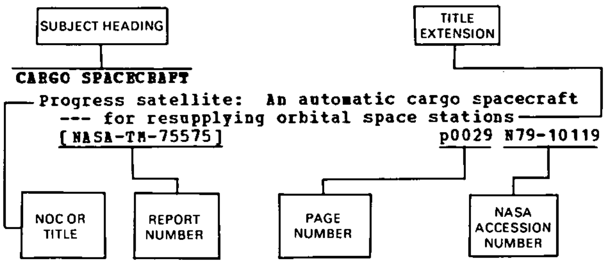

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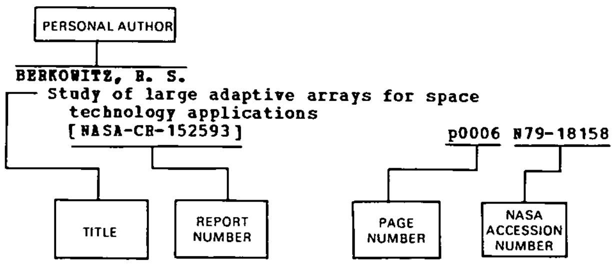

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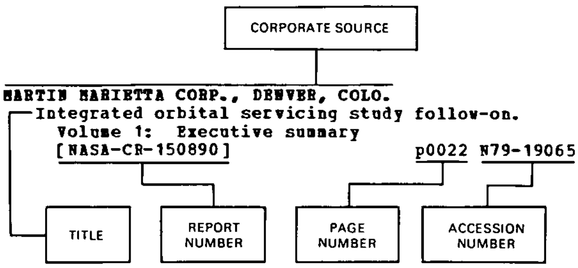

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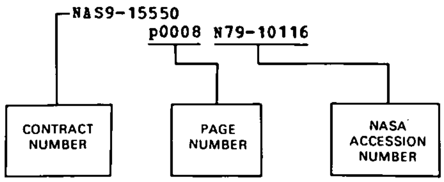

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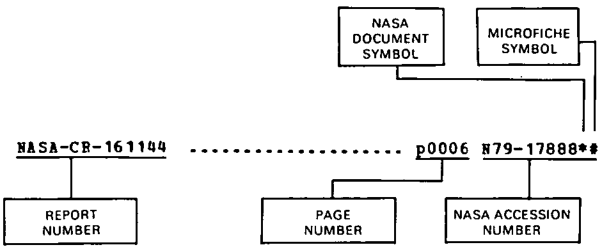

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15. Supplementary Notes

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16. Abstract

This bibliography lists 258 reports, articles, and other documents introduced into the NASA scientific and technical information system between July 1, 1979 and December 31, 1979. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design in the area of the Large Space Systems Technology (LSST) Program. Subject matter is grouped according to systems, interactive analysis and design, structural concepts, control systems, electronics, advanced materials, assembly concepts, propulsion, solar power satellite systems, and flight experiments.

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